THE USE OF VARIOUS BODY DEVELOPMENT INDICES FOR THE PREDICTION OF THE PERCENTAGE OF CLOSELY TRIMMED WHOLESALE CUTS

by

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INTRODUCTION

The livestock and meat industry has demonstrated great interest in the use of measurable live and carcass characteristics for the prediction of carcass meatiness.

Much research studying the relationships of various measurable live and carcass characteristics to the yield of the closely trimmed wholesale cuts as well as other indicators of carcass meatiness has been reported. The results of these studies do not indicate consistent and clear cut indications of the real relationships between these variables. Many of these studies are limited to a simple correlation analysis between these measurable characteristics and the various endpoints of meatiness. If the weight of lean or of cuts is used as the indicator of meatiness extremely high correlations result. However, if the percentage of lean or cuts is used as the indicator of meatiness negative correlations of low magnitude are generally obtained. In those studies where the effects of carcass weight are eliminated or held constant correlations between various indicators of body development and weight of lean or cuts are reduced considerably. On the other hand, in those cases where the percentage of lean or percentage of cuts was used as the indicator of meatiness, and where carcass weight was held constant, the correlations changed from negative to positive.

These changes in the magnitude of correlations after removing the effects of carcass weight would seem to indicate that the true relationship between various indices of body development and carcass meatiness or cutability are obscured by the effects of carcass weight. This study was undertaken to determine if a true relationship does exist between various body development indices and the yield of closely trimmed wholesale cuts and if these indices of body development can be incorporated into a prediction equation that will accurately predict the percentage yield of closely trimmed wholesale cuts.

REVIEW OF LITERATURE

One of the most difficult problems concerned with the evaluation of beef carcasses in relation to yield of useable meat is the selection of an end point that will consistently give a valid estimate of the true proportion of edible product. Complete physical separation of the entire carcass, while it does have the advantage of measuring the total fat, lean and bone is a laborious, time consuming and expensive procedure and is not practical. In addition it has the disadvantage of failing to consider the relative differences in value between cuts. Other end points have been considered as possible indices of carcass yield of edible meat. The percentage of the four primal cuts; round, loin, rib, and chuck both as individual cuts or as a composite, is commonly used as a criteria of cutability. The use of these cuts has the advantage of being easy to obtain without materially altering the value of the carcass. In addition the proportion of weight in these cuts does reflect value differences between carcasses. Separable fat, lean and bone of the 9-10-11th rib cut is often used as an index of relative proportion of fat, lean and bone of the entire carcass. This end point, while not as time consuming as separation of the entire carcass, does have the disadvantage of appreciably altering the wholesale rib cut and thereby affecting the value of the cut. Rib eye area is a commonly used criterion of muscling and can be obtained easily without affecting the value of the carcass.

Separable Fat, Lean and Bone of the 9-10-11th Rib Cut

Lush (1925) stated that the wholesale rib cut was representative of the ratio of fat, lean, and bone of the entire carcass.

Crown _et_ _al_. (1960) obtained correlations of .943, .976 and .733, all significant at the .01 level, between separable lean, fat and bone of the 9-10-11th rib cut and that of the entire carcass and this would indicate the 9-10-11th rib cut is a good predictor of separable lean and fat. Working with the twelfth rib cut these workers reported correlations of .818, .962 and .750 between separable lean, fat and bone of the twelfth rib cut and of the entire carcass.

Cole _et_ _al_. (1960) reported a correlation of .74 between separable lean of the 9-10-11th rib cut and separable lean of the carcass. This is considerably lower than that reported by Crown.

Rib Eye Area

A great deal of controversy exists concerning the value of rib eye area as an index of total lean or muscling. Cole _et_ _al_. (1960) reported on data from eighty-one steers, nine heifers and nine cows that represented a variety of grades from choice to utility. While not reported, it is assumed that considerable variation existed in carcass weight and degree of finish. They found correlations of .43 between weight of separable carcass lean and rib eye area. However with carcass weight held constant this correlation approached zero. These workers reported a correlation of .55 between rib eye area and separable lean of the 9-10-11th rib cut. This correlation was reduced to .35 with carcass weight held constant. It was also reported that area of loin eye was associated with only eighteen per cent of the variation in separable carcass lean and 5 to 30 per cent of the separable lean of the more valuable cuts. Holding carcass weight constant these workers reported correlations between loin eye area and weight of separable lean of the round, chuck and short loin of .06, .00 and -.08, respectively.

Considerable variation in area of rib eye exists dependent on the location in which it is measured. Cole _et al._ (1962) found correlations between area of rib eye and pounds of separable carcass lean, of .49, .58, and .55 for measurements taken at the last lumbar vertebra, the twelfth rib and the fifth rib, respectively.

Kline and Hazel (1955) found a correlation of .88 between loin eye area at the tenth and last rib of pork carcass. They found little improvement of accuracy in predicting lean cuts by measuring loin eye in more than one place. The correlations between per cent lean cuts and loin eye area at the tenth and last ribs were similar.

Pearson _et al._ (1956) working with pork carcasses studied the effectiveness of rib eye area at the tenth and last ribs to the ratio of fat to lean for estimating cutout values. Area of lean was found to be correlated .62 and .53 with per cent primal and lean cuts respectively when measured at the last rib and .59 and .52 when measured at the tenth rib. Area of lean in this study included both longissimus dorsi and multifidis dorsi muscles.

Dunn (1960) used loin eye area ratio in a correlation study between loin eye area and weight of trimmed wholesale cuts. This ratio was the square inches of loin eye area per hundred pounds of carcass weight. He found loin eye area ratio to have a correlation of .42 to total trimmed weight of wholesale cuts. These cuts were trimmed to a standard 1/4 inch exterior fat and included the round, loin, rib and square cut chuck. In this work both trimmed round weight and chuck weight had simple correlations of .39 to loin eye area ratio. Loin eye area ratio had a negative .06 correlation with untrimmed loin weight and a positive .17 correlation with trimmed loin weight. This would seem to indicate that loin eye area is a better measurement of round and chuck than it is of loin.

Goll et al. (1961) reported a correlation of .00 between loin eye area and per cent round, loin, rib and chuck. Holding carcass weight constant these workers found a correlation of .14. Holding weight constant they found correlations of .09, -.15, .27 and .11 between loin eye area and per cent round, loin, rib and chuck, respectively.

Gottsch (1962) compared loin eye area to loin eye area ratio and found loin eye area ratio superior to loin eye area in predicting weight of total lean from the round, loin, rib and chuck. This work was in agreement with Dunn in that loin eye area was found to be a better predictor of round lean than loin lean. This is due probably to the greater variation of fat trim on the loin.

Woodward et al. (1960) found correlations of .41 and .18 between rib eye area and weight and percentage of lean respectively, of the 9-10-11th rib cut. These workers found a correlation of .32 between area of rib eye muscle and pounds of edible portion in the 9-10-11th rib cut. Edible portion was not clearly defined however, it is assumed to mean closely trimmed bone out. Area of rib eye muscle was slightly negatively related

(-.02) to per cent edible portion of the 9-10-11th rib cut.

Ramsey *et al.* (1962) studied the relationship of the proposed yield grades to per cent fat, lean and bone of the entire carcass. In this work it was reported that when area of rib eye was omitted from the yield grade calculations, the resulting yield grades were more highly related to separable lean and fat than when it was included. Yield grade using the correction for rib eye area was negatively (-.75) related to per cent separable lean while yield grade not corrected for area of rib eye was negatively (-.79) related to per cent separable lean.

Murphey *et al.* (1960) reported a multiple correlation of .909 when relating fat thickness over the twelfth rib plus per cent kidney fat to per cent yield of "Bone-in" major retail cuts. Including area of rib eye in the multiple correlation only slightly improved the relationship to .917. When these same indicators were used in relationship to boneless retail cuts the inclusion of rib eye area resulted in an increase from a correlation of .871 to .916.

In nearly each case cited, area of rib eye muscle, when the effects of weight are eliminated, appears only slightly related to measures of muscling. The relatively large simple correlations would appear to be more a function of automaticity. Apparently, both increases in rib eye area and corresponding increases in weight of cuts or separable lean, are more related to carcass weight than they are to each other. Cole *et al.* (1960) reported a simple correlation of rib eye area to separable carcass lean of .43. In this work rib eye area was more highly related ($r = .53$) to carcass weight. Separable carcass lean was highly significantly related to carcass weight ($r = .77$). Cole *et al.* (1962) reported correlations of

.59 and .74 between area of rib eye and weight of separable lean and carcass weight, respectively. Dunn (1960) did not agree with this work. He found a negative correlation (r = -.16) between carcass weight and loin eye area ratio and a highly significant relationship (r = .42) between loin eye area ratio and weight of the trimmed wholesale cuts. This is difficult to understand; however, it can be partially explained by the fact that the cattle used in Dunn's work were very similar in weight. Goll et al. (1961) found correlations of .52 between loin eye area and carcass weight and .00 between loin eye area and per cent trimmed wholesale cuts. These workers found, using analysis of variance, that heavy weight carcasses in general are deeper sided, have greater round width, greater width and larger loin eye areas. In this work considerable variation in carcass size existed with the light weight group weighing between 430 and 470 pounds and the heavy weight group weighing between 630 and 670 pounds.

In a study comparing area of rib eye and edible portion, Cahill et al. (1959) reported a correlation of .68. Edible portion, as reported by these workers, meant closely trimmed to a maximum of three-eighths inch of exterior fat on any exposed surface.

Bray and Merkel (1957) found rib eye area to have a very low relationship with marbling and carcass grade. Carcass grade was highly correlated with marbling.

Woodward et al. (1960) was in agreement with Bray in that he reported area of eye muscle and fat thickness at the twelfth rib were not strongly related. With final weight held constant a slight negative relationship was found to exist between these two characteristics.

Zobriskey et al. (1959) studying relationship of lean cuts to various carcass measurements in pork carcasses reported loin eye area to be highly correlated (.57) with yield of the four lean cuts. They also reported negative correlations between backfat thickness and yield of the five primal cuts.

Boughton (1958) found correlations of .11 for steers and .08 for heifers, between area of rib eye and per cent wholesale cuts. This worker reported highly significant negative correlations of -.44 for steers and -.28 for heifers between 12th rib fat depth and per cent commercial round. Rib eye area was negatively correlated (r = -.07) with per cent commercial round in steers and positively (r = .17) in heifers.

Pearson et al. (1959) working with seven breeds of swine ranked the breeds on the basis of area of loin eye and found percentages of lean cuts to have marked inconsistencies. This would indicate that loin eye area does not closely reflect actual percentage yields of lean cuts if breed effect is ignored.

Hirzel (1939) in some of the earlier work with loin eye relationships to muscling studied the use of length, depth and "Shape Index" as possible indicators of muscling.

McMeekan (1939) found high correlations, all above .73, between total weight of muscle in pork and lamb carcasses and a combination of length and depth of the longissimus dorsi muscle. In this work the effects of carcass weight were not eliminated which partially accounts for the high correlations. McMeekan (1941) in a further study found very high correlations of .84 and .93 between cross sectional length plus depth of longissimus dorsi and twice length plus depth and total muscle weight of the carcass. In this work he concluded that a combination of length and depth of eye was superior to either of these measurements considered singly.

Palsson (1939) was essentially in agreement finding similar correlations between length and depth combinations of loin eye muscle and total carcass muscle. Length plus depth was correlated (.81) with total muscle weight. Twice length plus depth was less highly correlated (.73).

Wholesale Cuts

The possible use of particular cuts as predictors of yield of wholesale cuts or meatiness of a carcass has been studied by a number of workers. Dunn (1960) found that the weight of the chuck and round accounted for 27 to 76 per cent of the variation of total weight of trimmed wholesale cuts. Loin eye area ratio accounted for only 18 per cent. He found that carcass grade was negatively related (r = -.31) to total trimmed wholesale cuts. Carcass grade was negatively related (r = -.34) to trimmed round. Trimmed chuck was more highly correlated (r = .87) to total wholesale cuts than any other single wholesale cut. Each of the trimmed wholesale cuts was more highly related to total trimmed wholesale cuts than was loin eye area ratio. This would indicate that the square cut chuck is less affected by exterior finish than the other cuts. Another contributing factor in the high relationship of trimmed chuck to total trimmed wholesale cuts is the fact that the chuck accounts for a large proportion of the weight of the total wholesale cuts. It is interesting to note the relative changes in the level of correlation between trimmed and untrimmed cuts to total trimmed wholesale cuts. The levels of correlation between trimmed and untrimmed chuck and total trimmed wholesale cuts are .87 and .83. The relatively small change in magnitude of correlation would seem to indicate a minimum of trimmable exterior finish. The round, a cut which is ordinarily considered as a relatively minimally finished cut, showed considerably greater variation between trimmed and untrimmed weight and total weight of trimmed wholesale cuts, trimmed round (r = .76) and untrimmed round (r = .52). This would seem to indicate greater exterior trim fat on the round than on the chuck. Gottsch (1962) compared per cent of lean from the various cuts, to per cent total carcass lean. In actuality this worker's measure of lean might better be described as edible portion. He used the weight of the closely trimmed boneless retail cuts plus the lean trim as a measure of total lean. This would of course contain a higher proportion of fat than would separable carcass lean. He found essentially the same correlations of (r = .78) and (r = .77) between per cent lean from the round and chuck respectively and total carcass lean. He found correlations essentially in agreement with Dunn's for the relationship between the per cent of untrimmed round and chuck and total per cent carcass lean. The chuck appeared superior to the round as a predictor of total carcass lean with a correlation of .48 as compared to a correlation of .37. Both the per cent rib and loin were negatively related (r = -.05) and (r = -.14) to per cent total lean. The total per cent lean from the four wholesale cuts was highly significantly related, .91, to total carcass lean as might be expected. This work bears out that the leaner and larger cuts give the more accurate estimates of carcass lean. The per cent lean of the shank had a correlation of .20 to per cent total lean. While the foreshank is a lean cut it would not be expected to be as highly related to per cent total lean because of the relatively low fat percentage in comparison with other carcass components.

Green <u>et al.</u> (1955), studying the interrelationship of weights of particular wholesale cuts, found similar relationships. He found the chuck and round to have the highest relationship to the weight of the other wholesale cuts. This would be expected inasmuch as these were simple correlations and the relatively high level was primarily a function of weight. This is further evidenced by the fact that carcass weight was more highly related to weight of each of the cuts than was any particular cut interrelationship. When the effects of carcass weight were removed the relationship between weight of arm chuck and round was highly significant (r = .69). The relationship of arm chuck weight to trimmed loin weight was .34.

Orme et al. (1960) studied the value of weights of entire muscles for predicting total carcass lean. He found correlations of .78 between the weight of the longissimus dorsi muscle and total carcass lean holding carcass weight constant. The biceps femoris, largest outside round muscle, had a correlation of .97 to separable carcass lean holding carcass weight constant. This would seem to indicate the value of the round as an indicator of total carcass muscling. In this work sixty-four to ninety-two per cent of the variation in separable carcass lean was associated with weight of certain muscles. This work, it should be pointed out, was done on mature Hereford cows. The live animal weights ranged from 825 to 1410 pounds and the grades from high cutter to high commercial.

Cole et al. (1960) found separable lean of the round to more highly related to total separable lean of the carcass than either loin eye area or separable lean of the other major wholesale cuts. Simple correlations between separable carcass lean and separable lean of the following cuts were: round .95, chuck .93, sirloin .80, shortloin .75, rib .79, 9-10-11tth rib cut .74 and foreshank .81. These correlations are undoubtedly influenced by the high relationship of carcass weight to total separable lean which had a correlation of .77. Loin eye area was found to be inferior to separable lean of any of the cuts studied as a predictor of total separable carcass lean accounting for only 5 to 30 per cent of the variation of separable carcass lean or separable lean of any of the cuts studied. The above correlations were obtained with year and breed effects ignored. When breed effects were eliminated the correlations between loin eye area and separable lean of the various cuts were reduced from highly significant to non-significant in all cases except to the separable lean of the round.

In a study comparing the standard untrimmed wholesale cut method to a "retail trimmed" method, King et al. (1959) observed highly significant differences in yield of wholesale cuts measured by the "retail trimmed" method. The standard untrimmed method revealed little or no significant differences of wholesale cut yield between carcasses. In this study carcass weight varied from 204 to 745 pounds and the grades ranged from U. S. Standard to U. S. Choice. The "retail trim" method consisted of removal of all exterior fat to a uniform one-quarter inch depth. The average yield of loin, rib, round and chuck was 47.82 per cent and 37.25 per cent for the standard and "retail trimmed" cutting methods, respectively.

Butler et al. (1956) studying the variation of percentage yields of wholesale cuts found little variation between Hereford and Hereford-Brahman cross-bred steers. The estimated per cent bone was identical for both types of steers, namely 15.4 per cent. The Brahman x bred steers had 49.9 per cent of their carcass and the straight Hereford steers 48.8. There was almost no difference in rump or round weight and the rib and chuck weight were identical for both groups. These workers stated that there was a strong tendency towards proportional developing of muscle and bone among steers of the same age. Fat was found to be the greatest variable and as such should exert the greatest influence on cutting yields.

Fat Measurements

Various subjective and objective measurements of exterior fat have been studied as predictors of cutability. Inasmuch as exterior finish is the most variable of the three factors that effect percentage yield of trimmed cuts or percentage carcass lean, per cent fat would be expected to have predictive value. Clifton, reporting at the fifth annual Reciprocal Meats Conference, found a higher relationship of exterior fat to carcass grade than any of the studied indicators of muscling. Inasmuch as grade is more highly related to finish than conformation, it would be expected that high grading carcasses would have lower yields of trimmed cuts than lower grading carcasses. However Murphey et al. (1960) reported greater variation of yield of cuts in the prime and choice groups studied than in the good and standard grades. This would indicate that high yielding carcasses are found in the higher quality grade carcasses. This work did indicate that a greater proportion of the higher yielding carcasses, considering yield of closely trimmed boneless retail cuts, was found in the lower grading cattle. These workers found very similar correlations between a single fat thickness measurement taken at one-fourth of the cross sectional long axis of the longissimus dorsi muscle from the lateral edge and an average of three measurements taken at one-fourth, one-half and three-fourths the length of this muscle. The single measurement had a correlation of -.79 and the average of three measurements a -.81 to yield of boneless closely trimmed wholesale cuts. Gottsch (1962) reported a negative .70 correlation to closely trimmed boneless retail cuts for an average of three measurements and a negative .40 for a single fat thickness measurement. Dunn (1960) reported a negative .51 correlation for an average of three measurements and weight of total trimmed bone in wholesale cuts.

Ramsey et al. (1962) reported negative correlations of -.76 and -.73 respectively, for a single measurement and the average of three fat measurements and per cent separable carcass lean. These measurements were highly positively related to per cent separable fat with a single measurement correlated at the .82 level and the average of three at the .80 level. When those correlations were run on a within breed basis the magnitude of correlations were more in line with those found by Gottsch. These workers were in agreement with Clifton reporting a positive .79 relationship between per cent separable fat and carcass grade.

Woodward et al. (1960) reported correlations of .32 and .54 between an average of three fat thickness measurements and weights of separable lean and edible portion of the 9-10-11th rib cut, respectively. When correlated to percentage lean and edible portion of the same cut the reported correlations were a negative -.29 and a positive .58, respectively. These workers found a correlation of fat thickness with carcass grade of .28.

Dunn (1960) studied the value of fat depth probes for estimating total carcass exterior finish. This worker found that a fat depth probe in the short loin area was correlated (r = .63) to total fat trim. The correlation between an average of three measurements at the twelfth rib and total fat trim was .50. Both of these correlations were significant at the .01 level. Short loin fat depth and twelfth rib fat depth had a correlation of .54 to each other. Dunn found a highly significant negative correlation of -.49 with trimmed round, rib and loin to short loin fat depth.

Gottsch (1962) found similar relationships between short loin fat depth and twelfth rib fat thickness reporting a correlation of .58. He found a correlation of .65 between short loin fat depth and total carcass fat trim. This worker studied the relationship of fat trim from particular cuts to total fat trim. He found fat trim from the plate to have the greatest relationship to total carcass fat trim reporting a highly significant .79 correlation. Chuck and loin fat trim were both highly related to total fat trim with highly significant correlations of .75 and .72 respectively. Fat trim from the chuck had a highly negative .70 correlation with total carcass lean. This work was not in agreement with Dunn (1960) who found the loin fat trim had the highest relationship with total fat trim .89 and the chuck fat trim the lowest .55. The difference is probably due to the fact that Dunn was studying a weight-to-weight relationship and Gottsch was comparing a per cent to per cent relationship.

The per cent kidney fat has been considered as a possible indicator of yield of trimmed wholesale cuts. Goll et al. (1961) found per cent kidney fat and per cent trimmed wholesale cuts to be correlated at the negative .70 level. Holding carcass weight constant did not materially change the level of correlation. This worker found kidney fat negatively related to round and chuck weight but slightly positively related to loin and rib weight. This would be expected in that loin and rib are both cuts that are more affected by additional fat cover.

Murphey et al. (1960) reported a negative .66 correlation between per cent kidney fat and per cent yield of bone in retail cuts. Using a multiple correlation coefficient of an average of three fat measurements and per cent kidney fat to yield of bone in retail cuts these workers reported a multiple correlation of .909.

Various fat depth measurements as well as percentage of fat trim from various cuts appear to give the most reliable estimates of yield of trimmed cuts or carcass lean. Inasmuch as exterior finish is the most variable of the factors affecting yield of useable meat, this would seem to be a logical conclusion.

In work with swine, DePape and Whatley (1956) found highly significant negative correlations .66 and .58 between carcass back fat depth and per cent lean cuts and primal cuts, respectively. In this work they found that backfat probes of live hogs were more highly related with per cent primal cuts than were carcass back fat measurements. Hazel and Kline (1952) in work involving 96 hogs obtained similar results. An average of four carcass back fat measurements was negatively .45 correlated with per cent primal cuts. These same workers in a later study (1959) found higher correlations for live probes, negative .89 with per cent of lean cuts than carcass back fat measurements.

In studying the relationship of fat thickness to carcass grade, Hankins and Burke (1938) reported a correlation of external fat to carcass grade of .95. They found correlations of .90 between marbling of lean and carcass grade and .88 between marbling and external fat depth.

Wheat and Holland (1959) reported degree of marbling to be highly related to after ribbing carcass grade ($r = .89$). Conformation score was only slightly correlated .25 with after ribbing carcass grade and had an identical correlation with degree of marbling.

Tollis et al. (1959) found edible portion to bone ratio to be significantly related to fat trim ($r = .63$) for steers. These workers found per cent edible portion to be greatly influenced by fat trim.

Bone and Muscle Relationship

The possible use of various bone measurements as indicators of meatiness or muscling has been studied by many workers in the field. If a proportional relationship between muscle and bone exists the relative accessability of bone could make it a useful tool for evaluating meatiness.

Kropf (1962) working with pork carcasses, made an extensive study of the relationships of per cent and length of various bones and per cent lean cuts and specific gravity. This work indicated a positive relationship between per cent of certain bones and per cent lean cuts. However, the correlations were too low to be of value as predictors of cutability. Greater length of bone was associated with higher per cent of lean cuts, however length of the tibia, which had the highest correlation, accounted for only 27 per cent of the variability in yield of lean cuts. Circumference measurements and circumference to length relationships were not strongly related to either per cent lean cuts or carcass specific gravity.

Orme et al. (1959) found some interesting relationships between various bone measurements and carcass lean as determined by separation of the 9-10-11th rib cut. These workers, when holding carcass weight constant, found length of forecannon to have a correlation of .80 to per cent primal cuts. These cuts were made as described by Wellington (1957) and apparently were not trimmed. They found a correlation of .37 between forecannon length and per cent estimated carcass lean as determined by separation of the rib cut. Holding carcass weight constant gave consistently higher correlations between bone and percentage yields than between bone and weight yields. In all cases length and width were superior to weight or circumference measurements. When carcass weight was held constant only length of bone gave significant and positive relationships with per cent of lean or cuts. Removing the effects of weight, width and length measurements gave the best estimates of rib eye area accounting for 15-28 per cent of the variation. All relationships were negative indicating that with cattle of the same weight there is a tendency for larger rib eyes to be associated with shorter, lighter bones. When comparing the various bone measurements to weight and per cent of carcass lean, all were highly related to weight of carcass lean. These correlations approached zero, however, when compared to per cent carcass lean.

Orts et al. (1959) agreed in that they found a higher relationship between bone length and cut weight than between bone weight and cut weight. They found rather high simple correlations between bone weight to length ratios and weight of the total wholesale cuts. These correlations were reduced considerably when carcass weight was held constant. The simple correlation between hind cannon bone weight to length ratio and sum of the four wholesale cuts was .814, but when holding carcass weight constant was reduced to .25. These workers found hind cannon a better indicator of wholesale cut weight than forecannon. These workers found the highest relationship with round and loin and the lowest with rib, they did not report on relationships with the chuck weight.

Wythe et al. (1961) studied the relationship of various bone measurements to weights of closely trimmed wholesale cuts. When holding the effects of carcass weight constant, they found the weight of the tibia to be correlated (r = .65) to the retail trimmed boneless cushion round and to the sum of the retail trimmed chuck, rib and loin (r = .70). Tibia weight was correlated (r = .51) to area of rib eye. These workers found weight of various bones superior to weight length ratios as estimators of weight of cuts. They also found the tibia to be superior to the forecannon as an estimator.

Wythe (1958) reported simple correlations between various trimmed wholesale cuts and bone length and weight and found weight to be superior to length. In this work the femur and tibia were superior to both fore and rear cannons as predictors.

The possibility of various objective body measurements as predictors of muscling or meatiness is of great interest to the livestock industry as well as the meat industry. Body measurements, if they yield valid estimates of carcass muscling, could be an invaluable tool in the selection of live cattle for cutability.

Bailey _et al._ (1961) studied the relationship of loin eye area and various width and circumference measurements in lambs. These workers reported a simple correlation of .52 between circumference of thighs to loin eye area. Width of gigots, the joint between the hip and stifle joints, had a simple correlation of .59 to loin eye area. This measurement would correspond to the widest point of the rump on the live animal. These correlations were on young lambs of weaning age. For older lambs that had been fed from weaning to an average age of eight and one-half months, they reported a correlation of .77 between circumference of thighs and rib eye area when holding carcass weight constant. These workers found carcass weight more highly related to loin eye area on young lambs slaughtered at weaning age than on older fed lambs with simple correlations of .56 and .37 respectively. Circumference of forearm had a fairly high simple correlation of .39 to rib eye area but approached zero when carcass weight was held constant.

Goll et al. (1961) reported a correlation of .52 between hind leg length and per cent loin, rib, chuck, and round with the effects of carcass weight removed. It should be noted that these were untrimmed wholesale cuts. Depth of body, with carcass weight held constant, had a correlation of .55 with untrimmed wholesale cuts. None of the body width or depth measurements were very highly related to loin eye area when the effects of weight were removed.

Cole et al. (1960) reported simple correlations of .32 and .50 between loin eye area and round circumference and chuck width respectively. Round circumference had a correlation of .45 with weight of separable carcass lean. Length of leg was correlated (r = .53) with weight of separable carcass lean. Flank depth had the highest correlation of .59 to weight of separable carcass lean. Flank depth had the highest correlation (r = .59) to weight of separable carcass lean of any of the linear measurements studied.

Orme (1959) found that all the linear body measurements studied had relatively high simple correlations to loin eye area but all approached zero when the effects of carcass weight were removed. This would seem to indicate that the relationship of these measurements to loin eye area is primarily a function of weight.

MATERIALS AND METHODS

History of the Animals

Sixty-five Hereford steers owned by Clifford Houghton of Tipton, Kansas were the animals used in this study. These steers represented the progeny of four bulls, were long yearlings at the time of slaughter and had been managed and fed as a group from birth to slaughter. The steers were weaned in mid-September, 1961, and wintered on a concentrate-roughage growing ration until April 1, 1962. They were then put on full feed and fed until August 16, 1962. At slaughter these steers ranged in weight from 855 to 1225 pounds. The average weight was 1004.84 lbs with a standard error of 82.70 pounds. The carcasses from these steers ranged from 498 lbs to 749 lbs with a mean carcass weight of 616.75 lbs and a standard error of 61.70 lbs.

Each steer was individually identified and a weight recorded at the Houghton ranch prior to shipment to the Kansas City Stockyards. At this time five live subjective evaluations of external finish were made using a hedonic scale of one to seven. The points evaluated were the brisket, forearm, plate, loin edge and cod as per Table 1. The brisket and cod were evaluated by visual examination only. The forearm, plate and loin edge were handled as well as evaluated visually. A physical measurement of the length between the anterior edge of the hooks and the posterior edge of the pins was taken to the nearest one-tenth inch and recorded as rump length alive.

The steers were shipped to the Kansas City Stockyards and consigned

Table 1. Live subjective external finish evaluations (scoring system).

Brisket	Loin	Plate	Forearm	Cod
1. Extremely small	Extremely thin	Extremely thin	Extremely thin	Extremely small
2. Very small	Very thin	Very thin	Very thin	Very small
3. Small	Thin	Thin	Thin	Small
4. Modest	Modest	Modest	Modest	Modest
5. Moderate	Moderate	Moderate	Moderate	Moderate
6. Full	Thick	Thick	Thick	Full
7. Very full	Very thick	Very thick	Very thick	Very full

to the Maurer-Neuer Division of the John Morrill Company. The cattle were loaded at 7 P.M. August 16, and at 7 A.M. August 17 each steer was individually weighed at the Kansas City Union Stockyards and the weight recorded to the nearest pound.

The cattle were slaughtered according to approved packing plant procedures. Each carcass was tagged with its identifying number while on the kill floor to insure adequate identification in the coolers. Immediately after sticking and before the hide was removed the circumference of both forearms was recorded, to the nearest one-tenth of an inch. The point of measurement was determined by putting a steel tape on the foreleg from the coronary band of the hoof to the tip of the elbow. The midpoint between these two reference points was used as the point of measurement. Circumference of cannon was measured at the point of least circumference on the foreshin. Hide weights were obtained on each steer.

Carcass data were obtained from the right sides of the cattle. Gross

Table 2. Carcass quality indices (scoring system).

Finish Thickness	Finish Uniformity	Firmness of Lean	Lean Color	Maturity
1. Extremely thin	Extremely ununiform	Extremely soft	Very dark red	Young A
2. Very thin	Very ununiform	Very soft	Dark red	Average A
3. Thin	Ununiform	Soft	Slightly dark red	Old A
4. Moderately thin	Moderately ununiform	Moderately soft	Bright cherry red	Young B
5. Slightly thin	Slightly ununiform	Slightly soft	Light cherry red	Average B
6. Slightly thick	Slightly uniform	Slightly firm	Very light cherry red	Old B
7. Moderately thick	Moderately uniform	Moderately firm	—	Young C
8. Thick	Uniform	Firm	—	Average C
9. Very thick	Very uniform	Very firm	—	Old C
10. Extremely thick	Extremely uniform	Extremely firm	—	—

carcass data were taken on the entire 65 head. Length of rump was measured from the posterior edge of the last lumbar vertebra to the posterior edge of the pubis symphysis and recorded to the nearest one-tenth inch (Fig. 1, B-C). Length of loin was measured from the anterior edge of the first lumbar vertebra to the anterior edge of the pubis symphysis (Fig. 1, B-D).

Four round circumference measurements were taken and recorded. These were measured at 40, 50, 60 and 70 per cent of the length of the round with the 40 per cent point closest to the shank end (Fig. 1). Length of round was determined by measuring from the prominence of the articulating surface of the shank, after removal of the rear shin, to the anterior edge of the pubis symphysis (Fig 1, A-B).

Cross sectional area of rib eye was traced between the twlefth and thirteenth rib and measured with a compensating polar planimeter. Thickness of exterior finish over the twelfth rib was measured at 1/4, 1/2, and 3/4 the cross sectional length of the <u>longissimus dorsi</u> and recorded both as an average of three measurements and as a single measurement 3/4 the distance from the chine bone.

The carcasses were graded to one-third of a quality grade by the supervising grader of the Kansas City division of the federal grading service using a scale as outlined in Table 4. Grade information obtained included a score for conformation, amount and distribution of finish, color of external fat, per cent estimate of kidney fat, degree of marbling, firmness and color of lean, degree of maturity, and final quality grade. The scale used for these factors is outlined in Tables 3 and 4. All of these data were obtained after a 24-hour carcass chill. In addition a marbling score on the left side of the carcass and a final grade were obtained after

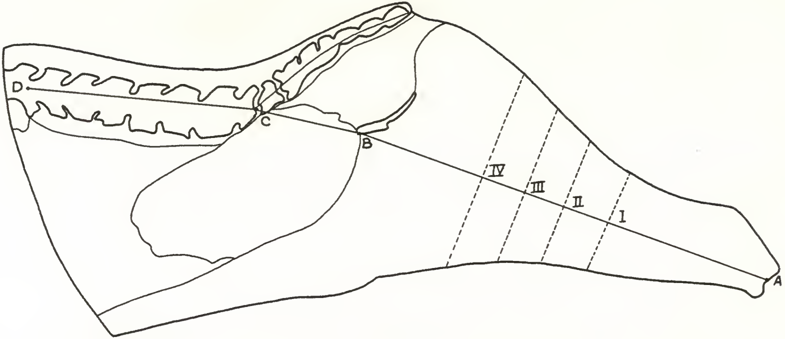

Figure I. Skeletal reference points of indicies of body development.

A to B length of round

B to C length of rump

B to D length of loin

I = 40%

II = 50%

III = 60%

IV = 70%

Circumference taken at the length of round

Table 3. Marbling score system.

	+	Ave.	-
Extremely abundant	36	35	34
Very abundant	33	32	31
Abundant	30	29	28
Moderately abundant	27	26	25
Slightly abundant	27	23	22
Moderate	21	20	19
Modest	18	17	16
Small	15	14	13
Slight	12	11	10
Traces	9	8	7
Practically devoid	6	5	4
Devoid	3	2	1

Table 4. Quality grade (scoring system).

	+	Ave.	-
Prime	24	23	22
Choice	21	20	19
Good	18	17	16
Standard	15	14	13
Commercial	12	11	10
Utility	9	8	7
Cutter	6	5	4
Canner	3	2	1

a 72-hour chill.

A previously selected random sample of thirty-two steers were broken into wholesale cuts and then closely trimmed, to a standard one-fourth inch fat trim. The wholesale rib cut was shipped to the meats laboratory of Kansas State University for further processing. The 6-7-8th rib cut was removed for cooking studies conducted by the Department of Home Economics. The twelfth rib cut was used for histological and chemical studies. The 9-10-11th rib cut was physically separated into fat, lean, and bone and the weights and percentages recorded to the nearest gram.

Statistical Analysis

These data were analyzed statistically. Simple correlations between all factors studied were obtained. In addition partial correlation coefficients, removing the effects of carcass weight, were obtained on selected variables. A multiple regression equation was obtained for prediction of the per cent closely trimmed wholesale cuts. The independent variables used to derive the multiple regression equation were in the order of: carcass weight, circumference of round at 40 per cent of the length, circumference of forearm, length of loin, and length of rump measured on the carcass.

Levels of significance were determined according to the method outlined by Snedecor (1956). For data involving the entire 65 head these significance levels are: at the .05 level (r = .245) and at the .01 level (r = .318) with 63 degrees of freedom. The significance level of the standard partial correlation coefficients for factors involving the entire 65 head are: at the .05 level (r^1 = .246) and at the .01 level (r^1 = .320) with 62 degrees of freedom. For data involving the 32 randomly selected carcasses the significance levels are: at the .05 level (r = .349) and at the .01 level (r = .449) with 30 degrees of freedom. The levels of significance for the standard partial correlation coefficients holding carcass weight constant are: at the .05 level (r^1 = .355) and at the .01 level (r = .456) with 29 degrees of freedom.

DISCUSSION AND RESULTS

Factors Influencing U.S.D.A. Quality Grade

The left side of these carcasses were graded after a 24 hour chill. At this time the federal grader, using the scoring systems previously mentioned, evaluated the carcasses for several factors. This grade will be referred to hereafter as 24 hour quality grade. In addition another grade and marbling score was made on the right sides after a 72 hour chill. These will be referred to as 72 hour grade and 72 hour marbling score. None of the live subjective external finish evaluations were significantly related to either 24 or 72 hour U.S.D.A. quality grade.

Of the grade factors evaluated by the U.S.D.A. grader, marbling score 24 hour chill was most highly related (r = .836) to U.S.D.A. quality grade 24 hour chill. Marbling score 72 hour chill was next most highly related (r = .619) to quality grade 24 hour chill. Of the other grade factors used by the federal grader only lean color (r = .339) was significantly related to final grade 24 hour chill.

U.S.D.A. grade 24 hour chill and U.S.D.A. grade 72 hour chill were highly significantly correlated (r = .682). However this means that only

46.5 per cent of the variability of U.S.D.A. grade 24 hour chill is explained by U.S.D.A. grade 72 hour chill. It would be difficult to determine if the unexplained variability between the grades made on different sides of the two carcasses is due to slight changes in the graders subjective standards or to actual differences between the two sides. The mean score for the left sides 24 hour chill was 16.50 as compared to 16.75 for right sides 72 hour chill. The standard error was identical .84. This would indicate a slight advantage for the right sides or for 72 hour chilling. These differences were not studied statistically.

Marbling score 24 hour chill was highly significantly correlated (r = .588) with marbling score 72 hour chill. However, only 34.6 per cent of the variation of one is explained by the other. Again this would indicate either a change in the graders standards or an actual change in marbling. The right sides chilled 72 hours had a slight advantage in mean score, 11.56 as compared to 11 for the left sides.

Marbling score 72 hour chill was highly significantly correlated (r = .909) to final grade 72 hour chill, accounting for 82.6 per cent of the variation observed.

Firmness of lean was highly significantly correlated (r = .322) to quality grade 72 hour chill. This is interesting inasmuch as firmness of lean was correlated (r = .000) to quality grade 24 hour chill.

Color of lean and quality grade 72 hour chill were significantly correlated (r = .305).

Of all the indices of quality used by the Federal grader only marbling accounted for sufficient variability in final grade to be of any value as a predictor of grade. Color of lean had some relationship to final grade but accounted for only 11.5 per cent of the variation and would be of little value as a predictor of grade.

Hide weight was significantly negatively correlated (r = .314) to quality grade 24 hour chill and was positively but not significantly correlated (r = .142) to quality grade 72 hour chill.

The per cent separable fat of the 9-10-11th rib cut was significantly (r = .433) related to quality grade 72 hour chill and non-significantly (r = .142) correlated to quality grade 24 hour chill.

Depth of fat measured at the thirteenth rib 3/4 the distance from the chine bone was significantly (r = .313) correlated to quality grade 72 hour chill. The sum of three fat depth measurements was not significantly correlated to either 24 hour or 72 hour quality grade. The other fat indicator studied, per cent trim from the 9-10-11th rib cut, was not significantly related to quality grade.

There was a definite pattern of negative relationship between the indicators of muscling or body development and U.S.D.A. grade. With the exception of rib eye area, length of rump alive and per cent separable lean of the 9-10-11th rib cut all of these physical measurements were more highly negatively related to 24 hour chill quality grade than 72 hour chill quality grade.

Circumference of round at 50 per cent of its' length had a greater (r = -.504) correlation to 24 hour chill quality grade than all other body development indices studied.

Circumference of round at 40 per cent of its length was highly significantly correlated (r = -.464). Length of round and length of loin were both highly significantly negatively related to 24 hour chilled carcass grade, (r = -.355) and (r = -.359), respectively. Circumference of forearm and cannon were significantly negatively correlated (r = -.294 and -.278) to 24 hour chill quality grade.

Only per cent separable lean of the 9-10-11th rib cut was highly correlated (r = -.451) to 72 hour chill quality grade. Of the remaining indices of body development studied only length of rump measured in the live animal and rib eye area with significant negative correlations of -.317 and -.278 had a statistically significant relationship to 72 hour chill carcass grade.

It would appear from these data that only marbling accounted for enough of the variation in carcass grade to be of any predictive value. The fact that the other quality indices included in the U.S.D.A. specifications were not particularly highly related to final quality grade could be the result of many factors. Marbling could be subject to greater variation than are the other factors studied thereby becoming the limiting factor in a graders evaluation of a carcass. For this population, marbling of the left sides had a standard error of 1.83 and the right side 1.92. The next highest standard error was for lean color .56 and firmness of lean .54. This would seem to indicate greater variability of marbling than of the other quality indices studied in this population.

For populations with greater initial variation in these quality indices the degree of relationship between them and final grade might be expected to be higher.

In general there is a tendency towards a negative relationship between quality grade and those indices of body development studied. This is caused by the relationship between these indices and carcass weight. Carcass weight

Table 5. Correlation coefficients between U.S.D.A. carcass grade and other factors studied.

Variables, U.S.D.A. Carcass Grade	24 hr chill	72 hr chill
Live fat evaluation of brisket	-.018	-.083
Live fat evaluation of plate	.038	.096
Live fat evaluation of loin	.082	.062
Live fat evaluation of forearm	.087	.153
Live fat evaluation of cod	.095	.191
Graders evaluation of conformation	-.101	.101
Graders evaluation thickness of finish	-.040	.182
Graders evaluation distribution of finish	-.048	-.024
Graders evaluation est. kidney fat	.024	.083
Graders evaluation firmness of lean	.000	.322**
Graders evaluation color of lean	.339**	.305*
Carcass grade 72 hour chill	.682**	--
Marbling 24 hour chill	.836**	.606**
Marbling 72 hour chill	.619**	.909**
Dressing %	-.243	-.150
Weight of hide	-.314*	.142
% fat 9-10-11th rib cut	.146	.433*
% bone 9-10-11th rib cut	.086	-.013
% lean 9-10-11th	.208	-.451**
% sum of round, loin, rib, chuck closely trimmed	.003	.121
% fat trimmed from round, loin, rib, and chuck	-.014	.298
Length of rump alive	-.227	-.317*
Circumference of cannon	-.278*	-.022
Circumference of forearm	-.294*	-.014
Length of rump carcass	-.203	-.053
Length of loin carcass	-.359**	-.069
Circumference of round, 40% of the length	-.464**	-.184
Circumference of round, 50% of the length	-.504**	-.219
Circumference of round, 60% of the length	-.140	.060
Circumference of round, 70% of the length	-.275*	-.093
Length of round	-.355**	-.070
Carcass weight	-.284*	-.070
Average of three fat depth measurements	-.168	.069
One fat depth measurement 3/4 length of L.D.	.147	.313*
Rib eye area	-.252*	-.278*
Carcass weight	-.284	-.070

*P < .05

**P < .01

is negatively correlated to both 24 and 72 hour carcass grade with correlation of -.284 and -.070 respectively. Many of these are statistically significantly correlated to 24 hour chill quality grade but these correlations approach zero between the same developmental indices and 72 hour chill grade.

Factors Influencing Weight and Percentage Yield of Closely Trimmed Round, Loin, Rib and Chuck

Much attention has been paid to the selection of a proper end point as a measure of cutability. The yield of closely trimmed wholesale cuts represents the major portion of the value of a beef carcass. In addition this measure of carcass value or cutability can be obtained without materially altering the value of the carcass. In this study simple correlation coefficients between various live and carcass measurements and the weight of trimmed round, trimmed loin and the sum of the closely trimmed round, loin, rib and chuck were obtained. These cuts were trimmed to a standard 1/4 inch fat depth.

All of the measurements obtained that were indices of body development were either significantly or highly significantly correlated to the weights of the individual cuts as well as to the weight of the sum of the four cuts with the exception of rump length measured in the live steer. All of the round circumferences were highly significantly related to the weight of the trimmed round. The correlations obtained were (r = .885, .816, .535, and .781) respectively for the 40, 50, 60, and 70 per cent of the length of round circumference measurements. These round measurements were also highly significantly correlated (r = .688, .655, .508 and .624) to trimmed loin. As would be expected these round circumference measurements were more highly correlated to round weight than to loin weight. Highly significant correlations (r = .802, .763, .511 and .723) were obtained between the 40, 50, 60 and 70 per cent circumference of round measurements respectively and the combined weight of the closely trimmed round, loin, rib and chuck. In each case the 40 per cent circumference measurement had the higher relationship and the 60 per cent circumference measurement the smaller. The 60 per cent circumference measurement, because of its position in relation to the fat collar, was probably more affected by the amount of exterior finish. This effect of fat cover over the round could account for the lower correlations. The 40 per cent circumference measurement was the measurement taken closest to the shank. The higher relationship obtained for this measurement and weight of the individual cuts as well as the sum of the four would indicate an advantage to those steers that carry their muscling deeper to the hock.

Length of round was highly significantly correlated (r - .758, .737, and .772) to weight of trimmed round, loin and the sum of four cuts, respectively.

Circumference of forearm was measured on both forearms and these measurements summed and correlations run to this combined statistic. Circumference of forearm was highly significantly related to the weight of round, loin and sum of four cuts. The correlations obtained were .825, .725 and .800, respectively.

The length of rump measurement taken on the live animal was not significantly related to any of the trimmed cuts. Length of rump as measured in the carcass was significantly correlated (r = .363 and r = .444) to weight of trimmed round and weight of four trimmed cuts, respectively.

Carcass rump length was highly significantly correlated (r = .504) to the weight of trimmed loin. This would indicate that agreement between rump length measured in the live animal and rump length measured in the carcass was not high. The simple correlation between these two measurements was in the order of .159. The mean rump length as measured in the live animal was 12.43 inch with a standard error of ±3.66. The mean rump length as measured in the carcass was 13.20 inch with a standard error of ±.67. This data points up the difficulty of determining accurate measurements from a live animal and particularly measurements that will correspond to measurements fixed by skeletal reference points.

Length of rump measured in the carcass was more highly related to the weight of the trimmed loin than to either trimmed round weight or the sum of the four trimmed cuts. This is really not too surprising inasmuch as the sirloin area is part of the anatomical area included in this measurement.

Length of loin as measured in the carcass was highly significantly correlated (r = .487, .644 and .587) to weight of trimmed round, trimmed loin and the sum of the four trimmed cuts. As expected loin length is more highly related to loin weight than to the other trimmed cuts.

Area of longissimus dorsi measured between the 12th and 13th ribs was highly significantly correlated (r = .534, .450, and .487) to the weight of trimmed round, trimmed loin and sum of the four trimmed cuts. While these correlations are highly significant they are of much less magnitude than either the forearm circumference or the round circumference correlations.

Most of the simple correlations between body development indices and weight of the trimmed cuts are of sufficient magnitude to be of some value

Table 6. Simple correlation coefficients between weight of trimmed round, loin, rib, and chuck and other factors studied.

Character studied vs	Trimmed round	Trimmed loin	Sum of trimmed round, loin, rib and chuck
Length of rump alive	.259	.189	.193
Length of rump carcass	.363*	.504**	.444*
Length of loin carcass	.487**	.644**	.587**
Circumference of round, 40%	.885**	.688**	.802**
Circumference of round, 50%	.816**	.655**	.763**
Circumference of round, 60%	.535**	.508**	.511**
Circumference of round, 70%	.781**	.624**	.723**
Circumference of round, sum of 4	.630**	.630**	.714**
Length of round	.758**	.737**	.772**
Circumference of forearm	.825**	.725**	.800**
Area of loin eye	.534**	.450**	.487**
Live subjective fat evaluation			
brisket	.360*	.397*	.417*
loin	.255	.314	.339
plate	.147	.189	.250
forearm	.295	.282	.360*
cod	.207	.154	.216
Fat depth one measurement	.141	.385*	.316
Fat depth av. of three	.141	.366*	.289
Carcass weight	.886**	.908**	.966**

*$P < .05$
**$P < .01$

as predictors of trimmed cut weight. The best of these, round circumference measured at 40 per cent of the length, accounted for 64 per cent of the variation in weight of the four trimmed cuts. This same index accounted for 78 per cent of the variation of trimmed round weight.

Carcass weight however was superior to the 40 per cent round circumference measurement as a predictor of the weight of the four trimmed cuts with a correlation of .966. Round circumference and carcass weight were essentially equal as predictors of trimmed round weight with each accounting for about 78 per cent of the variation in this cut.

On the basis of the high relationship between carcass weight and these cuts it would appear that to a large degree automaticity might explain the relatively high correlations between the other body development indices and cut weight. Table 7 lists the simple correlations between carcass weight and the other indices of body development studied. With the exception of rump length measured in the live steer, carcass weight and the other traits studied are all highly significantly correlated. This would indicate these traits are somewhat a function of body size. However, carcass weight accounts for only 58 per cent of the variation in the 40 per cent round circumference measurement. The 42 per cent residual variation not accounted for by carcass weight, in view of this measurements rather high relationship to the round weight and the weight of the four cuts, would seem to indicate possible value as a predictor of cut weight independent of carcass weight.

None of the fat indicators studied accounted for enough of the variation in cut weight to be of value as a predictor.

The percentage yield of trimmed cuts has a certain degree of inherent appeal as an end point or measure of cutability. It is after all the percentage relationship of the more valuable carcass components that determines value. There are some limitations, however, in using percentages as an end point. It must be kept in mind that when dealing with percentages when one of the components measured increases another must decrease. This decrease does not reflect an actual diminishing of the component, but only a proportional decrease. When studying the relationship of particular cuts as indicators of carcass value this must be kept in mind. As an example two carcasses might have rounds that make up 24 per cent of the

Table 7. Simple correlation coefficients between carcass weight and other indices of body development.

Character studied vs	Carcass weight
Length of rump alive	.125
Length of rump carcass	.367**
Length of rump loin	.493**
Circumference of round, 40%	.760**
Circumference of round, 50%	.765**
Circumference of round, 60%	.527**
Circumference of round, 70%	.732**
Circumference of round, sum of four	.723**
Length of round	.445**
Circumference of forearm	.757**
Area of loin eye	.445**
Live subjective fat evaluations	
brisket	.453**
loin	.439**
plate	.279*
forearm	.430**
cod	.223
Fat depth one measurement	.357**
Fat depth av. of three measurements	.293*

$^{*}P < .05$
$^{**}P < .01$

carcass in each case. In one of these carcasses the four cuts might represent 75 per cent of the carcass whereas in the other the four cuts might represent only 73 per cent of the carcass. It would be an error to call these carcasses equal in terms of cutability. Using the round as the sole indicator of value would however lead to this conclusion.

Table 8 lists the simple correlations between various factors and per cent of trimmed round, loin and the sum of the four trimmed wholesale cuts.

With the exception of length of loin none of the indices of body development were significantly correlated to the per cent of any of the

Table 8. Simple correlation coefficients between the per cent of trimmed round, loin, rib and chuck and other factors studied.

Character studied vs	Per cent trimmed round	Per cent trimmed loin	Per cent sum of 4 cuts trimmed
Length of rump alive	.246	.179	.197
Length of rump carcass	-.077	.335	.095
Length of loin carcass	-.111	.381*	.088
Circumference of round, 40%	.079	-.134	-.159
Circumference of round, 50%	-.063	-.230	-.295
Circumference of round, 60%	-.103	-.031	-.250
Circumference of round, 70%	-.066	-.222	.097
Circumference of round, sum of four	-.072	-.188	-.292
Length of round	-.039	.108	-.072
Circumference of forearm	-.034	-.033	-.142
Area of loin eye	.069	.041	.003
Live subjective fat evaluations			
brisket	-.277	-.133	-.323
loin	-.451**	-.270	-.497**
plate	-.290	-.191	-.215
forearm	-.351*	-.342	-.432*
cod	-.091	-.126	-.093
Fat depth one measurement	-.491**	.087	-.308
Fat depth av. of three measurements	-.351*	.186	-.165
Carcass weight	-.446*	-.179	-.520**

$^{*}P < .05$

$^{**}P < .01$

cuts studied. Loin length was correlated (r = .381) at the .05 level to per cent trimmed loin but was not significantly related to either per cent trimmed round or per cent sum of the four trimmed cuts.

Depth of fat one measurement was highly significantly and negatively correlated (r = -.491) to per cent trimmed round. However this index was not significantly correlated to either per cent trimmed loin or sum of the four trimmed cuts. Depth of fat average of three measurements did not appear to be so highly related to the cut percentages as was the measurement taken at a single site.

The live subjective fat evaluations had a definite negative trend in their relationship to the percentage trimmed cuts. Of these evaluations the loin appeared to be the best area for evaluation. Loin finish was highly significantly and negatively correlated (r = -.451 and -.497) to per cent trimmed round and the sum of four trimmed cuts, respectively. Exterior finish over the forearm was the only other subjective fat evaluation site that had a significant relationship to the per cent trimmed cuts. Forearm finish was significantly and negatively correlated (r = -.351 and -.432) to per cent trimmed round and per cent four trimmed cuts, respectively.

There was a highly significant negative correlation (r = -.520) between per cent four trimmed cuts and carcass weight. This would indicate that as carcass weight increased there was a tendency for the per cent of trimmed cuts to decrease. This is in accord with the observation that as carcass weight increases those indices of depot fat tend to increase.

Partial Correlation Coefficient Analysis

It would appear from the preceding material that simple correlation coefficients do not always reveal the real relationship between two variables. The use of cut weight as an end point produced simple correlations of good magnitude. These simple correlations were, however, influenced by the strong relationship of carcass weight to all variables studied. In order to examine the real relationship of various muscling or body development indices to the weight of the various cuts, the effects of carcass weight would have to be removed.

Some suggest that the percentage these cuts are of the carcass will serve as a suitable end point adjusted for carcass weight. It would appear however, that carcass weight is still exerting an influence on per cent cuts. This is evidenced by a strong tendency for the percentage of cuts to decrease as carcass weight increases.

Both of these end points, weight or percentage of weight in the wholesale cuts are appealing as end points. Simple correlations are not adequate in revealing the true relationship of measurable live and carcass traits to either end point. Standard partial correlation coefficient analysis as outlined by Snedecor (1956b) was used to study some of the more promising relationships revealed by the simple correlation coefficients.

Table 9 lists a number of standard partial correlation coefficients between various indices of body development and both weight and per cent yield of the four closely trimmed wholesale cuts holding carcass weight constant. It is interesting to note that for all practical purposes the magnitude of the correlation is the same regardless of whether the end point is weight or percentage of the carcass. This would indicate that other unrevealed factors that might be affecting these correlations are at least influencing them in the same direction. Carcass weight was apparently exerting its influence positively in the case of weight of cuts and negatively in the case of per cent yield of cuts.

These partial correlation coefficients reveal some interesting relationships. Length of loin was highly significantly related to both weight and percentage of trimmed loin and to the weight and percentage of the four closely trimmed wholesale cuts. Round circumference measured at 40 per cent of the length of round is highly significantly correlated to weight and percentage of round (r = .702 and .719) respectively, and significantly

Table 9. Partial correlation coefficients holding carcass weight constant.

Character vs	% 4 cuts trimmed	Wt 4 cuts trimmed	% loin trimmed	Wt loin trimmed	% round trimmed	Wt round trimmed
Rump length alive	.309	.282	.206	.182	.34	.322
Rump length carcass	.36*	.372*	.438*	.438*	.10	.088
Loin length	.463**	.492**	.548**	.539**	.140	.124
Round circumference, 40%	.425*	.404*	.003	.008	.719**	.702**
Round circumference, 50%	.187	.144	-.147	-.147	.486**	.463**
Circumference of forearm	.451*	.407*	.159	.138	.519**	.509**
Rib eye area	.306	.247	.137	.122	.334	.337
Round length	.482**	.51**	.333	.334	.430*	.412*
One measure rib fat	-.153	-.120	.164	.155	-.397*	-.405*

$^{*}P < .05$

$^{**}P < .01$

(r = .404 and .425) correlated to weight and per cent sum of four closely trimmed cuts. Loin length is apparently not strongly independently related to either percentage or weight of round. Round circumference is not independently related to loin weight or percentage. This would seem to indicate that loin length and round circumference each exert an effect on weight and per cent of the four closely trimmed cuts independently from the other. Length of rump parallels loin length in that it is significantly correlated with weight and percentage of loin but essentially unrelated to round weight or percentage. Circumference of forearm is highly significantly correlated (r = .519 and .509) to per cent and weight of round, respectively. Forearm circumference is significantly related (r = .451 and .407) to per cent and weight of the four closely trimmed cuts.

Round length interestingly is more highly related to the sum of the four trimmed cuts than to either round or loin. This measurement yielded highly significant correlations of .482 and .51 to per cent and weight of four closely trimmed cuts and significant correlations of .430 and .412 to per cent and weight of trimmed round. Round length tended to be related to weight and percentage of trimmed loin with non-significant correlations of .334 and .333 respectively to these end points.

Rib eye area was not significantly related to either trimmed loin, round or sum of four closely trimmed cuts. Rib eye area had a tendency to be more highly related to trimmed round than to trimmed loin. Non-significant correlations of .334 and .337 were obtained between rib eye area and per cent and weight of round respectively. Rib eye area was apparently not related to loin percentage or weight yielding non-significant correlations of .137 and .122, respectively.

Multiple Correlation and Regression Analysis

The partial correlation coefficients, holding carcass weight constant, indicated some relationships between various body development indices and the per cent yield of the closely trimmed wholesale cuts. This suggested the possibility of adjusting the measurements of body development for carcass weight. The adjustment was made by dividing the measurements by the hundredweight of carcass. This data will be referred to as adjusted for carcass weight. Table 10 lists the simple correlations obtained for the unadjusted data. Table 11 lists the simple correlations obtained after adjusting the data for carcass weight. The adjusted data improves the magnitude of the correlations in each case. The correlations between adjusted data and the end point, per cent closely trimmed wholesale cuts, are all highly significant correlations. The correlations between these same body development indices not adjusted for carcass weight and the per cent closely trimmed wholesale cuts are not significant.

The intercorrelations between these body development indices are also improved after adjusting for carcass weight. The simple correlation between forearm circumference and round circumference for the unadjusted data was .764. After adjusting for carcass weight the correlation increased to .920. This would indicate that the adjustment reduced the residual variance between these two indices. The other intercorrelations were all improved after adjusting the data.

Figure 2 illustrates the effect of adjusting the data upon the regression on the percentage of closely trimmed wholesale cuts. The lower half of the figure is a graph of the relationship of loin length unadjusted for

Table 10. Simple correlations between various indices of body development.

	Forearm circumference	50% round circumference	Loin length	Rump length	% trimmed round, loin, rib, & chuck
Carcass weight	.752**	.760**	.493**	.367*	-.520**
Forearm circumference		.764**	.319	.258	-.132
40% round circumference			.362*	.352*	-.159
Loin length				.719**	.088
Rump length					.095

*P < .05 **P < .01

Table 11. Simple correlations between various body development indices/divided by the hundred-weight of carcass.

	Forearm circumference	40% round circumference	Loin length	Rump length	% trimmed round, loin, rib, & chuck
Carcass weight	.913**	.897**	.897**	.829**	-.520**
Forearm		.920**	.847**	.80**	.674**
40% round circumference			.851**	.821**	.662**
Loin length				.934**	.665**
Rump length					.633**

*P < .05 **P < .01

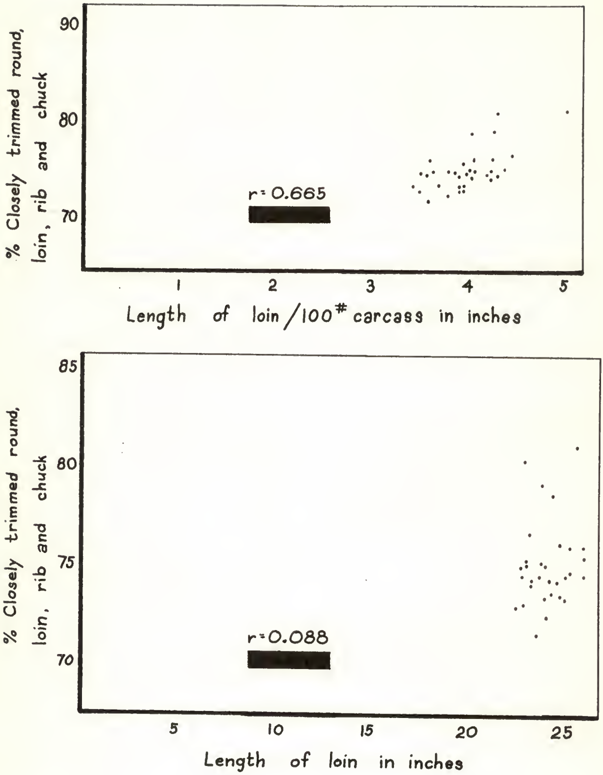

Figure 2. Linear relationship of loin length uncorrected and loin length per hundred weight of carcass and percent closely trimmed wholesale cuts.

carcass weight and the per cent closely trimmed wholesale cuts. The relationship between these two variables is essentially non-linear. The upper half of the figure illustrates the relationship of the length of loin per hundred pounds of carcass to the per cent closely trimmed wholesale cuts. The relationship between these variables is a positive linear trend. The relatively high correlations between these adjusted indices of body development and the per cent yield of closely trimmed wholesale cuts suggested their inclusion in a multiple correlation. Table 12 lists the multiple correlations obtained between various combinations of these indices and the per cent yield of closely trimmed wholesale cuts.

Carcass weight alone had a correlation of .520 to per cent four cuts. Carcass weight plus circumference of round improved the correlation to .683. Carcass weight and circumference of forearm yielded a multiple correlation of .714. The combination of carcass weight and forearm circumference accounted for 50.99 per cent of the variation in per cent yield of wholesale cuts. Carcass weight and round circumference accounted for 46.65 per cent. The addition of length of loin to carcass weight and circumference of forearm increased the multiple relationship to .808 thus accounting for 65.29 per cent of the variability of per cent closely trimmed wholesale cuts.

Circumference of round measured at 40 per cent of the length of round in combination with carcass weight and length of loin was not as highly correlated (R = .768) as carcass weight, circumference of forearm and length of loin (R = .808). This would seem to indicate that circumference of forearm may be superior to circumference of round as a predictor of per cent closely trimmed wholesale cuts. Inasmuch as forearm circumference is not directly measuring a component of these cuts its value as a predictor

Table 12. Multiple correlation coefficients between various combinations of body development indices per 100 lbs of carcass weight and the per cent of the closely trimmed wholesale cuts.

Indice	R
Carcass weight	.520**
Carcass weight, circumference of round	.683**
Carcass weight + circumference of forearm	.714**
Carcass weight + circumference of forearm + length of loin	.808**
Carcass weight + circumference of forearm + length of rump	.764**
Carcass weight + circumference of round + length of loin	.768**
Carcass weight + circumference of round + length of rump	.721**
Carcass weight + circumference of forearm + circumference of round	.743
Carcass weight + circumference of forearm, circumference of round, length of loin	.819**
Carcass weight + circumference of forearm, circumference of round, length of loin + length of rump	.821**

*$P \angle .05$

**$P \angle .01$

must be derived through its relationship to one or more of the cuts making up the four. While not studied statistically in this report, the strong relationship of the per cent four cuts to forearm circumference may come through a relationship between the chuck and the four cuts.

The inclusion of carcass weight, circumference of forearm, circumference of round and length of loin resulted in a multiple correlation of .819. This is a slight improvement over the multiple correlation of .808 when circumference of round was not included in the multiple correlation.

By including all five variables a multiple correlation of .821 was obtained. Thus the inclusion of all five variables in a multiple correlation accounted for 67.40 per cent of the variation in yield of closely trimmed wholesale cuts in the population studied. The standard deviation of yield of closely trimmed cuts was 2.15 or a variance of 4.62. A 67.4 per cent reduction in this variance should reduce it to 1.80 per cent. A regression equation should, therefore, produce estimates of the yield of closely trimmed wholesale cuts to an accuracy of ± 1.34 per cent.

These five variables were used to develop a multiple regression coefficient by the method outlined by Snedecor (1956c). The equation for predicting the per cent yield of closely trimmed cuts is as follows: per cent closely trimmed wholesale cuts is equal to -8.49 + .046 (carcass weight) + 4.6 (adjusted circumference of forearm) + 3.43 (adjusted circumference of round) + 5.63 (adjusted length of loin) - 1.44 (adjusted length of rump).

Table 13 lists the actual observed yields of closely trimmed wholesale cuts and the predicted values derived by using this regression equation formula. The multiple correlation between the observed values and the actual values is .821. The greatest error of prediction occurred in the case of steer 1033 where the predicted value was 3.65 per cent less than the observed value. The predicted value for steer 1106 was identical to the observed value. The variance between the actual and predicted values for per cent trimmed wholesale cuts for the 32 steers was 1.55 and the standard error ± 1.25. The slight difference between these values and those obtained from the multiple correlation analysis is due to rounding off.

Table 13. Actual observed yields of closely trimmed wholesale cuts versus the values predicted by the regression equation.

Steer No.	Y Observed values	Y^1 Predicted values
1025	75.62	75.99
1035	73.76	74.07
1107	73.17	71.88
1121	74.96	74.49
1129	74.87	74.42
1131	74.83	74.04
1132	76.12	74.26
1133	75.16	74.63
1004	74.81	75.16
1013	79.47	77.92
1032	75.42	76.99
1034	73.57	74.47
1057	74.40	74.87
1059	80.72	78.10
1066	72.70	74.60
1072	73.19	73.18
1082	73.50	71.41
1095	75.97	75.26
1102	73.24	74.19
1111	75.32	75.21
1136	74.51	76.22
1014	81.36	81.72
1015	76.24	75.31
1033	78.80	75.15
1046	74.37	73.09
1058	75.05	75.21
1096	75.50	76.42
1104	74.62	75.82
1106	76.89	76.89
1115	73.87	74.23
1127	74.67	74.53
1141	76.23	75.99

Variance of Y to $Y^1 = 1.55$

Standard error of Y to $Y^1 = \pm 1.25$

SUMMARY

Sixty-five steers owned and fed by Cliff Houghton of Tipton, Kansas were the animals used in this study. A random sample of 32 steers were selected from the sixty-five head for detailed carcass analysis.

Simple correlation coefficients were obtained between all characteristics studied. Live animal observations included: subjective evaluations of finish at the brisket, forearm, plate, loin and cod; and length of rump measured between the hooks and pins. Carcass observations included: carcass and conformation grade, marbling score taken after 24 and 72 hour chill, a U.S.D.A. graders evaluation of thickness and distribution of finish, estimation of kidney fat, firmness of lean and color of lean. Weight of hide and carcass weight were observed. Physical measurements of the carcasses included: length of round, loin and rump, circumference of forearm, circumference of round measured at 40, 50, 60 and 70 per cent of the length of round, fat depth at the 13th rib, and rib eye area. The preceding measurements were taken on all 65 head.

Additional observations made on the 32 randomly sampled steers included: weight and per cent of fat, lean and bone of the 9-10-11th rib cut, weight and percentage of closely trimmed round, loin, rib and chuck. The measurements of round, loin and rump length as well as the circumference of forearm and round were also adjusted by dividing the actual measurement by the hundred weight of carcass.

Partial correlation coefficients were obtained between various indices of body development and the per cent of trimmed wholesale cuts removing the effects of carcass weight.

A multiple regression equation was calculated using carcass weight, circumference of forearm adjusted for weight, circumference of round adjusted for weight, length of loin adjusted for weight and length of rump adjusted for weight as the independent variables. The percentage yield of the closely trimmed wholesale cuts was the dependent variable.

None of the live subjective external finish evaluations were significantly related to U.S.D.A. carcass grade. Marbling score was highly significantly related to final U.S.D.A. grade. The only other grader evaluation significantly related to final carcass grade was lean color. Lean color did not, however, account for enough of the variation in grade to be of any value as a predictor of grade. Final grade after 24 hour chill was highly significantly correlated to final grade 72 hour chill ($r = .682$). Marbling score 24 hour chill was highly significantly correlated ($r = .588$) to marbling score 72 hour chill.

There was some relationship indicated between the various fat measurements taken and 72 hour chill quality grade. The correlations obtained, however, were of low magnitude and no conclusions should be drawn from these low relationships.

There was a definite trend toward negative relationships between U.S.D.A. grade and the various indices of body development studied, i.e., length of loin, etc. This is due to the relationship between these measurements and carcass weight. Carcass weight is negatively correlated to U.S.D.A. grade.

This study would seem to indicate a definite relationship between the body development indices studied and cutability as measured by the percentage yield of closely trimmed wholesale cuts. This relationship is not apparent until the effects of carcass weight are removed in some manner. In this study simple correlation of essentially zero or negative correlations were obtained between these body development indices and per cent closely trimmed wholesale cuts. Partial correlation analysis, removing the effects of carcass weight, produced highly significant correlations between these same variables. Adjusting these body development indices by dividing the measurements through by the hundred weights of carcass produced highly significant correlations between these adjusted indices and per cent closely trimmed wholesale cuts. These correlations were of sufficient magnitude to indicate their value as predictors of per cent yield of closely trimmed wholesale cuts. The incorporation of carcass weight, adjusted forearm circumference, adjusted round circumference, adjusted loin length and adjusted rump length in a multiple regression equation produced a prediction equation capable of estimating yield of closely trimmed wholesale cuts to an accuracy of ± 1.25 per cent. This would indicate the importance of removing the effects of carcass weight in order to uncover true relationships between body development or muscling indices and per cent yields of trimmed cuts as carcass lean or other end points that represent lean expressed as a percentage of carcass weight.

Much of the literature concerning the relationship of live animal and carcass characteristics to carcass leanness minimize the value of muscling or body development indices for the prediction of yield of carcass lean. Fat depth or other indices of finish have most often been suggested as possible indicators of lean yield. Area of rib eye is the only muscling or body development index incorporated in the proposed U.S.D.A. yield grade prediction equation. Unfortunately rib eye area cannot be easily evaluated on a live animal and is therefore of minimal value as a tool for live animal evaluation. All of the indices of muscling or body development used in the regression equation in this study can be seen readily in the live animal. Proper use of these indices could lead to more accurate live animal estimations of carcass yields of trimmed wholesale cuts.

The relationship of circumference of forearm adjusted for carcass weight to the yield of closely trimmed wholesale cuts ($r = .674$) would seem to indicate this as a particularly worthy area for close evaluation of the live animal.

Circumference of forearm can be readily observedin the live animal and in some cases accurately measured. In this study this measure corresponds essentially to a live animal measurement in that it was taken before the hide was removed.

The regression equation suggested in this thesis incorporates only measures of body development and does not include any direct measure or evaluation of exterior finish. The author does not suggest the incorporation of this formula as an industry tool for evaluating the yield of closely trimmed wholesale cuts. The sole purpose for the development and presentation of this formula was to indicate the influence body proportion has on the percentage yield of these cuts. The relatively high degree of accuracy of prediction obtained by the use of this formula on the 32 carcasses points out the need for careful evaluation of muscle development as well as trim fat.

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THE USE OF VARIOUS BODY DEVELOPMENT INDICES FOR THE PREDICTION OF THE PERCENTAGE OF CLOSELY TRIMMED WHOLESALE CUTS

by

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Various live animal and carcass traits have been used in studies to predict the yield of closely trimmed wholesale cuts. In most of the studies involving various indicators of body development poor correlations with measures of meatiness were found. When the effects of carcass weight were removed the correlations between various body development indices and per cent closely trimmed wholesale cuts improved.

This study was undertaken to determine if true relationships between these body development indices and closely trimmed wholesale cuts do exist.

Sixty-five steers were used in this study. Six live and 24 carcass characteristics were studied on the 65 head. Fourteen additional carcass characteristics were studied on a random sample of 32 carcasses. Simple correlation coefficients were calculated between all characteristics. Partial correlation coefficients holding carcass weight constant were determined for selected variables. A multiple regression equation was calculated incorporating five body development indices as the independent variables and per cent closely trimmed wholesale cuts as the dependent variable.

The live characteristics studied included: subjective external finish evaluations of the brisket, forearm, loin, plate and cod, and length of rump measured from the hooks to the pins. Carcass characteristics studied on all 65 head included: carcass and conformation grade, marbling score taken after a 24 as well as a 72 hour chill, a U.S.D.A. graders evaluation of thickness and distribution of external finish, estimation of kidney fat, firmness of lean and color of lean. Hide weight and carcass weight were recorded. Physical measurements of the carcass included: length of round, loin and rump, circumference of forearm, circumference of round measured at 40, 50, 60 and 70 per cent of the round length, fat depth at the 13th rib and rib eye area.

Additional observations made on the 32 randomly carcasses included: weight and per cent of fat, lean and bone of the 9-10-11th rib cut, weight and percentage of closely trimmed wholesale cuts. In addition the length measurements of round, loin and rump as well as the round and forearm circumference measurements were adjusted for carcass weight by dividing them through by the hundred weight of carcass.

Only marbling (r = .909) accounted for enough of the variation in U.S.D.A. grade to be of any value as a predictor of grade. There was a definite trend toward a negative relationship between the indices of body development studied and U.S.D.A. grade. This was due primarily to the relationship of these indices and carcass weight.

The simple correlations between the various length and circumference measurements studied and per cent trimmed wholesale cuts were in the order of zero to slight but non-significant negative relationships. The simple correlations between these same indices and trimmed cut weight, however, were all highly significant. Partial correlation coefficients holding carcass weight constant were highly significant between these body development indices and either weight or percentage of closely trimmed wholesale cuts. The correlations obtained to these two end points were essentially the same for all the body development indices studied. Loin length holding carcass weight constant for example was correlated r = .463 to per cent four wholesale cuts and r = .492 to the weight of these cuts. This indicates that carcass weight is obscuring the true relationship that exists between these body development indices and per cent trimmed wholesale cuts.

By adjusting the body development indices for carcass weight simple correlations obtained between these indices and per cent trimmed wholesale cuts were highly significant.

Carcass weight plus four adjusted body development indices, were used as independent variables and per cent closely trimmed wholesale cuts as the dependent variables in a multiple regression analysis.

An equation for predicting the per cent closely trimmed wholesale cuts is as follows: per cent closely trimmed wholesale cuts is equal to -8.49 + .046 (carcass weight) + 4.6 (adjusted forearm circumference) + 3.43 (adjusted round circumference) + 5.63 (adjusted loin length) - 1.44 (adjusted rump length). The application of this formula to the measurements of the 32 steers resulted in prediction estimates that had a standard error of ± 1.25 when compared to the observed values of closely trimmed wholesale cuts.

This study would seem to indicate a true relationship between body development indices and per cent trimmed wholesale cuts. This relationship however, is not apparent until the effects of carcass weight are removed.