THE RELATIONSHIP OF BONE TO MUSCLE IN BEEF CARCASSES

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Introduction

Considerable interest has arisen among meats research personnel within the last few years on size of bone as an indicator of muscle development. This interest is nothing new as beef cattle producers, cattle feeders, cattle buyers and beef processors have for years been concerned about the amount of bone in cattle and its economic importance. Lush in 1926 stated, "The whole problem of size of bone in its relation to meat value, to the desirabilities of cattle as feeder cattle and to the desirability of cattle for range--beef production is a large one".

Little consistency has been shown in live animal visual appraisal as we often demand heavy boned breeding cattle and then do an "about face" and "praise" slaughter steers for possessing quality and refinement of bone. Bone characteristics are fundamentally determined by inheritance; however, the level of nutrition probably has some influence on the development of bone. Since muscles are attached to bones and their chief purpose is to operate or move the bones, it seems logical that their size and shape is associated with the size and shape of bones.

Several major factors must be considered when one undertakes to find the relationship of bone to muscling:

1. Accurate, useable indicators of bone thickness both on the live animal and in the carcass.
2. Variations in amount and distribution of fat.
3. Variations in age, weight and perhaps breed and previous environment.
4. An accurate, easily obtainable measure of muscling.

Considerable work has been done or is presently underway in the field of bone-muscle relationships, but very little has been published on the subject as such. There are conflicting reports and ideas in the published literature.

Review of Literature

Hammond (1921, 1932) McMeekam (1940, 1941), Palsson (1939) and others in England and New Zealand have completely dissected many thousands of meat animals (mainly swine and sheep, but some cattle), separating, weighing and measuring each individual muscle and each individual bone in the body. This work

involves a slow, meticulous separation of the tissues using scalpels, forceps, and scissors while keeping the cut covered as well as possible with damp towels to avoid evaporation. These workers have found a strong positive correlation between the weight of bone in each animal and the weight of muscle tissue. McMeekan (1956) stated "So strong is this relationship that the weight of muscle could be determined within one percent if the weight of the cannon bones are known". He also said, "On the average fine boned animals will kill out with a smaller percentage of lean meat and a larger percentage of fat at the same weight then will a stronger, thicker boned beast".

Walker (1958) has found correlations of .9/ between cannon weight and muscle weight and between total bone weight and muscle weight of Jersey heifers. In this work each muscle was removed and dealt with as an entity. Walker (1958) further reported that she used weight/length ratio as an indicator of bone thickness.

Callow (1948) reported that the ratio between weight of muscular tissue and bone increases during fattening and when carcasses contain over twenty percent fatty tissue the percentages of muscular tissues, bone tissue, tendon, etc., all decrease as the percentage of fatty tissue increases.

Hankins et al (1943) observed a significant difference between the muscle-bone ratio of beef and dual purpose shorthorns and also a significant difference between muscle bone ratios of the progeny of sires within each type. This indicated that muscle bone ratio is a rather definitely inherited characteristic. Correlations between muscle bone ratio and live animal measurements gave little indication that selections could be made on the basis of conformation as evaluated by such measurements.

Iush (1926) reported the percentage of leg bones (front and rear shanks) to be very good indicators of the percentage of gone in the dressed side of beef, but that this was largely a secondary effect of the primary factors of age and fatness. Little or no evidence of any relation between dressing percent and percentage of bone was found when the degree of fatness was constant.

Workers in the Bureau of Animal Industry, U.S.D.A. (1935) and Hankins et al (1946) found the percentage of bone and lean in the nine-ten-eleven rib cut provided a basis for estimating the bone and lean content of the dressed beef carcass. This has been substantiated by Cole et al (1958) and others.

Weseli et al (1958) and Good (1958) reported a simple correlation coefficient of .22 and a partial correlation coefficient (among steers of similar weight) of .11 between trimmed cannon circumference and ribeye area from 153 Angus, Hereford and Shorthorn steers entered in the 1956 International Carcass Contest. Significant, but small correlations were found when live bone score and live measurements (circumference of left metacarpus and frontal and lateral measurements midway between the knee and pastern joint) were correlated with clean metacarpus measurements (metacarpus freed of all excess tissue and measured in the same manner as live measurements). This study indicates that live animal measurements are not too useful for predicting actual bone measurements.
Merkel and Boughton (1958) found nonsignificant correlations between live front shank cannon circumference and loin eye area from 53 Hereford heifers and 30 Hereford steers when the effect of weight was removed. These workers reported nonsignificant partial correlations between area of round muscles and live front cannon circumference in both steers and heifers, but they did find highly significant simple and partial correlations between live cannon circumference and percent commercial round and between combined percent rib, loin, round and chuck and cannon circumference in heifers. These same correlations were not significant in steers. This indicates differences in muscle-bone relation due to sex. Merkel further stated that certain head measurements were not well associated with muscling characteristics.

Arthaud (1958) reports low simple and partial correlations between live measurements (circumference of front and rear shank and length of front and rear shank measured from the break joint to the dew claw) and area of ribeye on 50 head of cattle slaughtered in 1957.

Butler et al (1956) concluded that bones tend to develop proportionally in beef animals. Muscles are attached to bones at their origin and insertion, so muscle weight in different wholesale cuts tends to be proportionate.

Experimental

Detailed slaughter, carcass and bone data were obtained from 73 Hereford and Brahman Crossbred steers and 16 Hereford and Hereford x Angus heifers. The slaughter procedure was essentially as recommended by Deans (1951). Both sides of the carcasses were cut by procedures described by Hankins and Howe (1946). Measurements were made in a manner described by Naumann (1951).

The procedure used in obtaining bone data is outlined below.

1. Weigh removed shanks and feet and head.
2. Remove feet, phalanges, tendons and other extraneous matter from metacarpus and metatarsus.
3. Weigh and measure length (with calipers) of both left and right cleaned metacarpus and metatarsus.
4. Weigh and measure length of both left and right cleaned tibia. (Tibia minus tuber calcis.)
5. Weigh and measure length of both left and right cleaned femur.
6. Weigh and measure length of both left and right cleaned Radius Ulna. (Minus carpal bones.)
7. Obtain width (lateral) and depth (frontal) measurements of metacarpus and metatarsus at midpoint of length with sliding vernier caliper.
8. Saw metacarpus at midpoint of length, trace and compute cross-sectional area with planimeter.
9. Calculate weight/length ratios by dividing the weight of each bone by its length.

10. All bones were kept in the cooler and cleaned and weighed as quickly as possible to prevent loss from evaporation.

The rib, chuck, loin and round were given a retail trim so that all fat in excess of 1/4 to 3/8 inch and excess bony portions were removed. These trimmed cuts were used as indicators of muscling as they were thought to be more uniform in fat content than wholesale cuts. The longissimus dorsi muscles (rib eye) of each carcass were traced at the twelfth rib and a planimeter was used to determine the cross section area in square inches.

Results

Analysis of the data from the heifers and Brahman crossbred steers has not been completed.

A number of simple correlation coefficients were computed using data from 28 Hereford steers which were fed for 215 days, represented six herds, and averaged 559 pounds of chilled carcass with a range of from 426 to 715 pounds.

Highly significant correlations were found between the weights and between the lengths of metacarpus, metatarsus, tibia, femur and ulna-radius. (Table 1)

<table>
<thead>
<tr>
<th>Bone Weight</th>
<th>Metatarsus</th>
<th>Tibia</th>
<th>Femur</th>
<th>Ulna-Radius</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metacarpus</td>
<td>.960**</td>
<td>.936**</td>
<td>.987**</td>
<td>.947**</td>
</tr>
<tr>
<td>Metatarsus</td>
<td>.959**</td>
<td>.912**</td>
<td>.971**</td>
<td></td>
</tr>
<tr>
<td>Tibia</td>
<td>.967**</td>
<td>.942**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Femur</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bone Length</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metacarpus</td>
<td>.969**</td>
<td>.857**</td>
<td>.797**</td>
<td>.881**</td>
</tr>
<tr>
<td>Metatarsus</td>
<td>.976**</td>
<td>.806**</td>
<td>.883**</td>
<td></td>
</tr>
<tr>
<td>Tibia</td>
<td>.959**</td>
<td>.966**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Femur</td>
<td></td>
<td>.954**</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Significant at .01 level

These high correlations are further proof that bones develop proportionately both in length and weight.

Highly significant correlation coefficients between trimmed bone weights and weights of certain beef cuts, as well as area of eye muscle, are shown in Table 2.
Table 2. Correlations of trimmed bone weights with certain beef cut weights and area of eye muscle. 1958.

<table>
<thead>
<tr>
<th>ITEM</th>
<th>Meta-carpus</th>
<th>Meta-tarsus</th>
<th>Tibia</th>
<th>Femur</th>
<th>Ulna-Radius</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sum Loin, Rib, Round (rump on. regular whls. cut)</td>
<td>.654**</td>
<td>.676**</td>
<td>.737**</td>
<td>.721**</td>
<td>.762**</td>
</tr>
<tr>
<td>Sum of Retail Trimmed Rib, Chuck and Loin</td>
<td>.690**</td>
<td>.709**</td>
<td>.783**</td>
<td>.773**</td>
<td>.811**</td>
</tr>
<tr>
<td>Trimmed Boneless Cushion Round</td>
<td>.635**</td>
<td>.680**</td>
<td>.760**</td>
<td>.769**</td>
<td>.793**</td>
</tr>
<tr>
<td>Area of Eye Muscle</td>
<td>.645**</td>
<td>.690**</td>
<td>.686**</td>
<td>.635**</td>
<td>.707**</td>
</tr>
</tbody>
</table>

**Significant at .01 level

Correlations of bone lengths with weights of various beef cuts and area of eye muscle are shown in Table 3.

Table 3. Correlations of bone lengths with weights of various beef cuts and area of eye muscle. 1958.

<table>
<thead>
<tr>
<th>ITEM</th>
<th>Meta-carpus</th>
<th>Meta-tarsus</th>
<th>Tibia</th>
<th>Femur</th>
<th>Ulna-Radius</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sum Loin, Rib, Round (rump on. Regular whls. cut)</td>
<td>.575**</td>
<td>.589**</td>
<td>.792**</td>
<td>.823**</td>
<td>.812**</td>
</tr>
<tr>
<td>Sum Retail Trimmed Rib, Chuck and Loin</td>
<td>.582**</td>
<td>.582**</td>
<td>.782**</td>
<td>.831**</td>
<td>.817**</td>
</tr>
<tr>
<td>Trimmed Boneless Cushion Round</td>
<td>.585**</td>
<td>.603**</td>
<td>.806**</td>
<td>.847**</td>
<td>.813**</td>
</tr>
<tr>
<td>Area of Eye Muscle</td>
<td>.537**</td>
<td>.483**</td>
<td>.629**</td>
<td>.693**</td>
<td>.634**</td>
</tr>
</tbody>
</table>

**Significant at .01 level

The highly significant correlation coefficients of weight/length ratios of certain bones with weights of various beef cuts and area of eye muscle are shown in Table 4.

Table 4. Correlations of weight/length ratios of certain bones with weights of various beef cuts and area of eye muscle. 1958.

<table>
<thead>
<tr>
<th>ITEM</th>
<th>Weight-Length Ratio</th>
<th>Meta-carpus</th>
<th>Meta-tarsus</th>
<th>Tibia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sum Loin, Rib, Round, Chuck (rump on. regular whls. cut)</td>
<td>.579**</td>
<td>.623**</td>
<td>.583**</td>
<td></td>
</tr>
<tr>
<td>Sum Retail Trimmed Rib, Chuck and Loin</td>
<td>.648**</td>
<td>.676**</td>
<td>.656**</td>
<td></td>
</tr>
<tr>
<td>Trimmed Boneless Cushion Round</td>
<td>.615**</td>
<td>.675**</td>
<td>.639**</td>
<td></td>
</tr>
<tr>
<td>Area of Eye Muscle</td>
<td>.612**</td>
<td>.699**</td>
<td>.589**</td>
<td></td>
</tr>
</tbody>
</table>

**Significant at .01 level

These correlations look promising and indicate that a strong positive relationship between bone thickness (weight/length ratio) and muscling
(trimmed boneless cushion round, ribeye area, etc.) existed in the 28 steers in this study. It is realized, however, that some part-whole correlations resulted from these comparisons and no adjustment was made for weight or age differences.

A great deal of work is still needed in this field, since the composition of beef carcasses is becoming increasingly important to the beef producer, processor and consumer. We are looking for reasonably accurate, simplified methods of detecting muscling and percentage edible portion in live cattle. Perhaps some measure of bone thickness will give us this criteria. We are searching for better ways to determine bone thickness both in the live animal and in the carcass. We are striving to find the upper and lower limits of bone thickness as related to muscle development.

I think these problems can and will be solved in the near future, which in turn will be beneficial to all segments of the beef cattle industry.

Literature Cited


Cole, J. W. 1958. Comparisons of the mean percentage separable fat, bone and lean of the carcass with that of the mean percentage of separable fat, bone and lean of selected cuts of the carcass. Personal communication.


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MR. COLE: I would say that is very good, and I think the people in Texas should be congratulated on this type of work. It is meticulous, it is hard, and it is something that we all have to do if we are going to help to solve these problems we are faced with in beef carcass evaluation.

Now in working out this program the committee suggested topics, and I should like to say at this time, Vern, that if anybody has any idea for the committee he should feel at liberty to contribute the suggestion because we would like to have it even though the person doesn't happen to be on the Beef Carcass Evaluation Committee. I am sure the chairman next year will welcome any suggestions that are submitted.
I must admit that we have a most unique report here, and the committee planned it that way, I am sure, to save the best until the last. We have a lady on our committee, and she is a grand, capable person. Miss Cover is going to talk to us about an approach to measuring beef tenderness. (Applause)

MISS SYLVIA COVER: Mr. Cahill, Mr. Cole and Members of the Reciprocal Meat Conference: I am afraid I cannot live up to all the nice things that have been said about me, but I do appreciate being invited to speak.

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