RELATIVE GROWTH WITHIN THE BOVINE MUSCULATURE

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Important factors in carcass composition are the proportions of the major tissues, muscle, fat and bone and the distribution, particularly of muscle and fat over the carcass. Differential growth patterns of muscle, fat and bone as well as the major factors contributing to this differential growth have recently been described by Berg and Butterfield (1968). Normally the percentage of muscular tissue in a carcass increases following birth, then decreases as the fattening phase begins. Fat percentage continuously increases and bone percentage decreases. The relative proportions of muscle, fat and bone in a carcass can thus be greatly influenced by stage of development or weight at slaughter. In normal slaughter ranges, as weight increases muscle percentage decreases, fat percentage increases and bone percentage decreases. Major variation occurs between the proportions of muscle and fat with bone percentage remaining relatively more constant.

Plane of nutrition, genotype, and sex also influence carcass composition. A high plane of nutrition increases the percentage of fat, a low plane retards fat and possibly muscle development. So called early maturing breeds of cattle enter the fattening phase of growth at lighter weights than late maturing breeds and have a higher proportion of fat at similar weights. Heifers fatten at lighter weights than steers and steers at lighter weights than bulls other factors being equal. Knowledge of relative tissue growth and the various influencing factors can lead to feeding and management systems which are designed to produce optimum carcass composition from all breeds, types and sexes of cattle.

Perhaps of greater importance than gross carcass composition is the distribution of muscle and fat in the various parts of the carcass in relation to the possibility of increasing the proportion of high-priced cuts at the expense of lower-priced regions. Fat distribution and/or muscle distribution may affect proportions of wholesale or retail cuts from a carcass. It is well known that fat is deposited differentially in various regions. Luitingh (1962) showed how the fattening process affects proportions of different cuts by a relatively greater increase in the ventral parts and in the areas of major fat depots. Although fat distribution is implicated as the most important factor contributing to differences in carcass proportions, it was long thought and still held by some that muscle distribution also has a major influence. The remainder of this paper will attempt to examine variability in muscle distribution and factors which influence relative muscle growth and proportions in the bovine carcass.

RELATIVE MUSCLE GROWTH

Relative muscle growth has been studied by anatomical dissection of slaughtered animals of various ages, weights and breeds (Butterfield and Berg, 1966a). Allometric growth coefficients were calculated for individual muscles and classified into growth impetus groups indicating their relative

growth. Muscles which showed a steady growth impetus relative to total muscle were given three monophasive growth impetus classifications of "high", "average" and "low". "High impetus" indicated a proportionately faster rate of growth than total muscle and a growth coefficient greater than 1.0, "low impetus" muscles grew at a proportionately slower rate than total muscle with a growth coefficient of less than 1.0 and "average impetus" muscles maintained a constant proportion relative to total muscle. The monophasic growth impetus groups are schematically illustrated in Figure 1 on a log-log scale used for classification purposes and in Figure 2 as a percentage of total muscle.

Some muscles were found to have diphasic growth patterns in that their pattern of growth changed at some stage in postnatal development. Diphasic growth patterns classified were "high-average", "average-high" and "low-average" and their growth patterns are illustrated in Figure 3. Most of the muscles which showed diphasic patterns finished their initial stage of differential growth early in postnatal life. Berg and Butterfield (1968) reported that over the first age phase (0-84 days of age) 21 muscles representing 41.4% of the total musculature, showed growth impetus patterns significantly different from "average". In the remaining four age phases, from three to eight muscles representing from 4 to 9% of total muscle showed growth impetus patterns significantly different from "average". This was taken to indicate that major differential growth within the musculature takes place soon after birth and would play a minor role in affecting the composition of animals of normal slaughter weights. As the foregoing results were obtained from animals of variable nutritional and genetic background, data from more controlled experiments will be necessary in order to sort out any nutritional, genetic or other effects.

INFLUENCE OF RATE OF GROWTH ON MUSCLE WEIGHT DISTRIBUTION

It was once widely held that rate of growth would influence muscle weight distribution and thus carcass proportions. The loin as a high-priced area was classed as late maturing and rapid growth was supposed to result in increasing the proportion of this region. Since most differential muscle growth seems to occur soon after birth, this was considered an appropriate phase in which to investigate the effect of rate of growth on differential muscle growth. An initial experiment involving calves grown at two rates was described by Berg and Butterfield (1968). The rates of muscle growth in the two groups is shown in Figure 4. Muscles with "high-average" growth impetus are plotted in Figure 5 against the age of the animal and in Figure 6 against total muscle weight. When comparisons were made on an age basis the differential growth of this group of muscles was retarded but, when compared on the basis of total muscle weight, rate of growth had no differential effect. Slow growth merely slowed the whole process down in a normal allometric manner relative to total muscle growth. Similarly, muscles with a "low" growth impetus pattern take longer to decline to their adult proportions in animals on a poor nutritional regime and the proportion of "average" impetus muscles is unaffected by plane of nutrition.

Butterfield, Johnson and Berg (1968) reported a further experiment where 3 groups of calves were grown at widely differing rates, one group very fast, one at a moderate rate and the third group held at their birth weight for 70 days and then grown moderately fast. Serial slaughter was done based on live weight and individual muscles were dissected and weighed.

"High", "average" and "low" impetus groups of muscles were examined from animals on each of the three planes of nutrition. A growth coefficient of 1.12 for "high" impetus muscles was common to all 3 planes of nutrition, while 1.0 described the "average" muscles and 0.89 the "low" impetus muscles. These results emphasize the need to compare relative muscle weight on the basis of similar total muscle weights.

INFLUENCE OF RELATIVE MUSCLE GROWTH ON PROPORTIONS OF COMMERCIALLY IMPORTANT MUSCLE GROUPS

Butterfield and Berg (1966b) described growth impetus patterns for 9 anatomical groupings of muscles and compared these to previously described comparisons on a percentage basis (Butterfield, 1963). Both classifications are listed in Table 1. An experiment is underway at the University of Alberta to attempt to assess the validity of their importance relative to muscle distribution. Four calves were slaughtered and dissected shortly after birth (from 12 to 27 days of age) to establish a base for differential muscle growth. Serial slaughter of heifers, steers and bulls was then carried out for animals in the range of 250 to 500 kg. live weight and 8 to 14 months in age. All animals were sired by Shorthorn bulls from a variety of dams of 2 years of age. Calves were nursed on their dams to approximately 6 months of age (except those slaughtered early) and were then self-fed until slaughter on a 73% barley, 22% oats, 5% protein-mineral-vitamin-supplemented ration. Brome-alfalfa hay was limited to 2 lb. per head per day.

The percentages of total muscle in each of the standard muscle groups are shown in Figures 7 to 10 for calves (C), heifers (H), steers (S), and bulls (B) relative to the total muscle weight in one side of the carcass. Each point represents 4 animals except the 3 heavier groups for each sex respectively where only 2 animals per group were available to date.

There is good agreement of the growth patterns indicated in Figures 7 to 10 and those proposed in Table 1 for 6 of the 9 standard muscle groups. However, Group 1 (proximal pelvic limb) is listed as high-average or low in Table 1 but follows a low or average-low pattern in Figure 7. Plotting of other data from Butterfield and Berg (1966a) has led us to the tentative conclusion that this group of muscles may have a very early rise in percentage followed by a continuous decrease i.e. a high-low pattern. The data in Figure 7 are not complete enough to detect such a rise if it exists. Group 2 muscles (distal pelvic limb) appear to follow a reasonably constant low impetus pattern.

Group 3 muscles (surrounding spinal column) seem to follow a high-average pattern of growth in Figure 8 rather than average as shown in Table 1. The growth coefficient for the M. longissimus dorsi (the largest muscle in this group) was given by Butterfield and Berg (1966a) as 1.12 (high) in the first phase of growth and not significantly different from 1.0 thereafter and the growth pattern shown in Figure 8 for Group 3 corresponds to the pattern of this muscle. Group 4 muscles (abdominal wall) agree in Figure 8 and Table 1 with a high pattern for heifers and tending toward high-average for steers and bulls.

Group 5 muscles (proximal thoracic limb) show a low-average growth impetus pattern in Figure 9 in agreement with Table 1. The muscles of the distal thoracic limb (group 6) have a similar pattern to the proximal group and low-average impetus appears the best designation.

Growth patterns of muscles of the thorax and neck are plotted in Figure 10. Group 7 (thorax to thoracic limb) has a high growth impetus and group 8 (neck to thoracic limb) follows an average-high pattern both in agreement with Table 1.

Group 9 (neck to thorax) is listed as low-average in Table 1 but Figure 10 shows a high impetus pattern for bulls and a near average pattern for heifers and steers. Butterfield (1963) described this group as very late developing and therefore the expected upturn may not have developed in the relatively young animals represented in Figure 10.

The three sexes appear to have similar proportions in muscle groups 2, 5, 6, 7. Bulls seem to have higher proportions in muscle groups 8 and 9 and heifers show higher proportions in groups 3 and 4. These trends have not been tested statistically.

Although the preceding results show that proportions of individual muscles and anatomical muscle groupings do change during the course of normal development due to differential muscle growth, it would be premature to comment on the economic implications of these changes except that those changes which do occur are not in the direction of more desireable carcass proportions i.e. group 1 and group 3 do not increase after the initial phase. It should be mentioned also that only weight of muscle has been considered and composition changes in individual muscles must be determined before final interpretations can be made.

These preliminary results indicate the need for establishing normal growth patterns of muscles and muscle groups previous to setting up comparisons involving muscle distribution between breeds sexes and nutritional or other treatments. It seems adviseable to make comparisons at an equal total muscle weight or along curves established by serial slaughter of experimental groups. Butterfield (1965) compared the muscle distribution of five breeds from diverse backgrounds and found little difference in proportions of any of the standard muscle groups except the abdominal muscle group. This may indicate that at normal slaughter weights muscle proportions are reasonably constant over a diversity of genotypes and environmental conditions. More controlled experiments are necessary to resolve these and other questions.

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TABLE I[1)]

COMPARISON OF INTERPRETATION OF ANALYSIS OF GROWTH OF 'STANDARD MUSCLE GROUPS' USING GROWTH COEFFICIENTS (HUXLEY, 1932) AND DIRECT COMPARISON OF PERCENTAGE VALUES

Muscle group	Growth coefficient "b"	Direct comparison of percentages (Butterfield, 1963b)
1. Proximal pelvic limb	High-average or low	Late
2. Distal pelvic limb	Low	Early
3. Surrounding spinal column	Average	Average
4. Abdominal wall	High-average or high	Late
5. Proximal thoracic limb	Low-average	Early
6. Distal thoracic limb	Low-average or low	Early
7. Thorax to thoracic limb	High	Very late
8. Neck to thoracic limb	Average-high	Very late
9. Neck to thorax	Low-average	Very late

1) From Butterfield and Berg, 1966b.

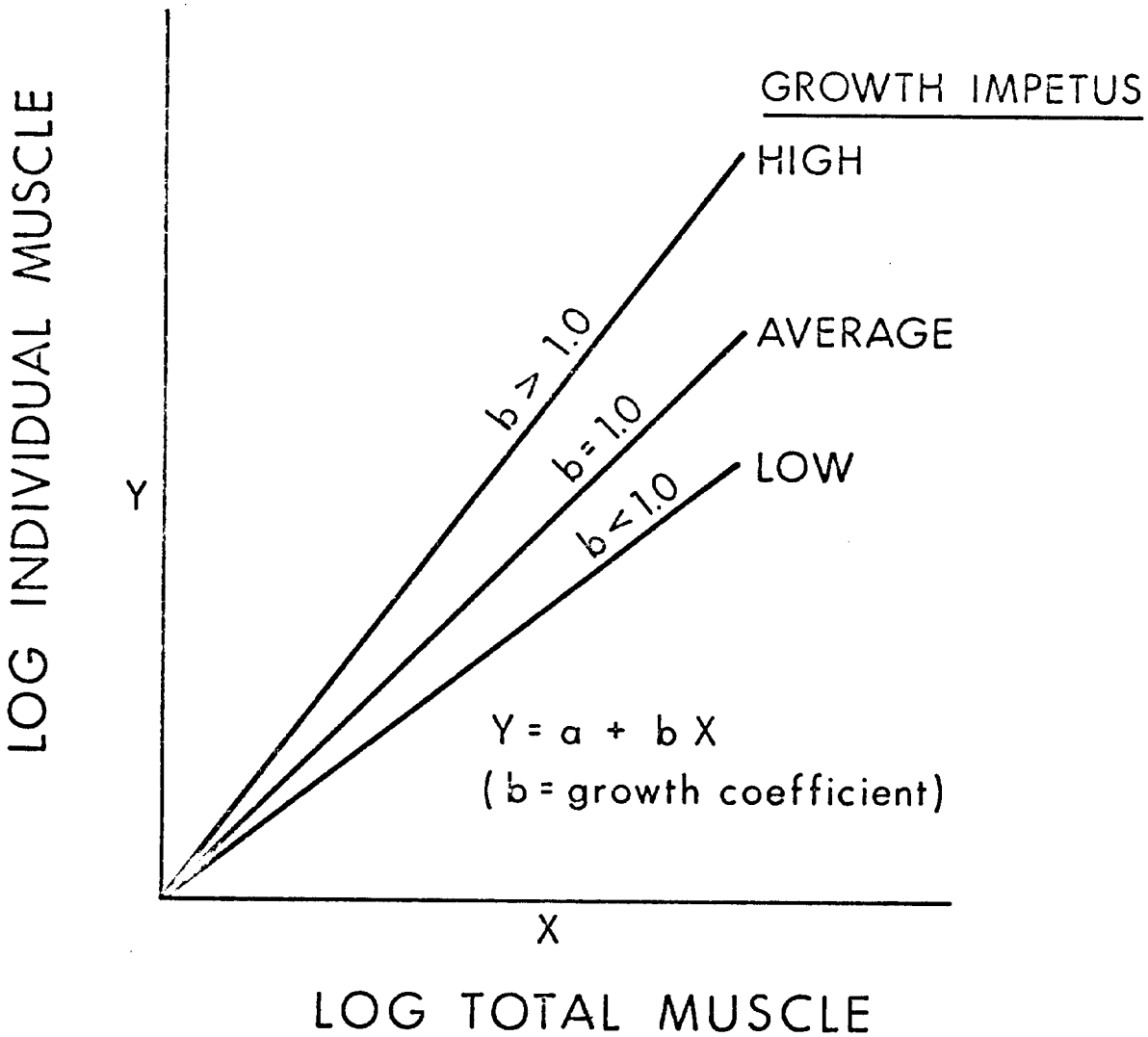

Figure 1:

Schematic Representation of Monophasic Muscle Growth Impetus Groups on a Log-log Scale.

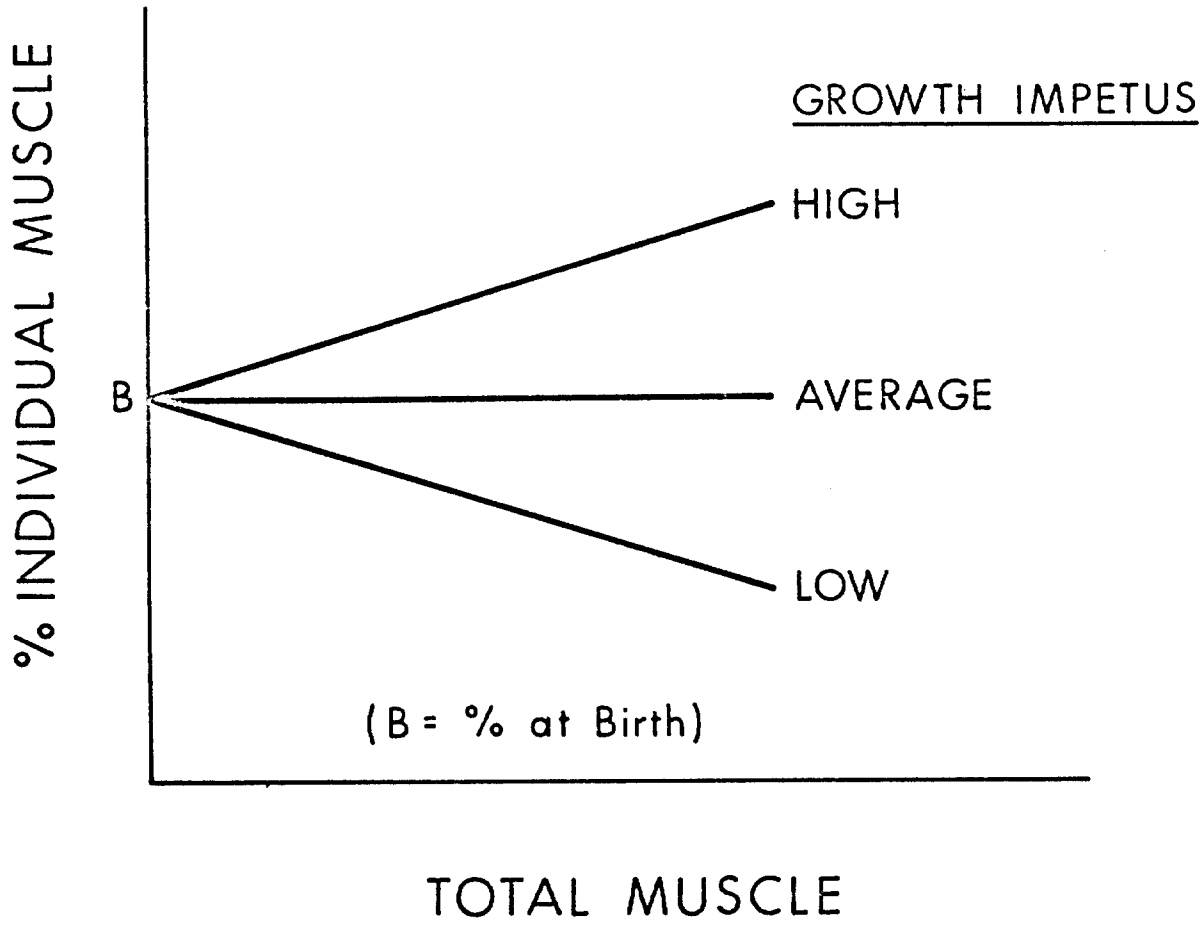

Figure 2:
Schematic Representation of Monophasic Muscle Growth Impetus Groups as a Percentage of Total Muscle.

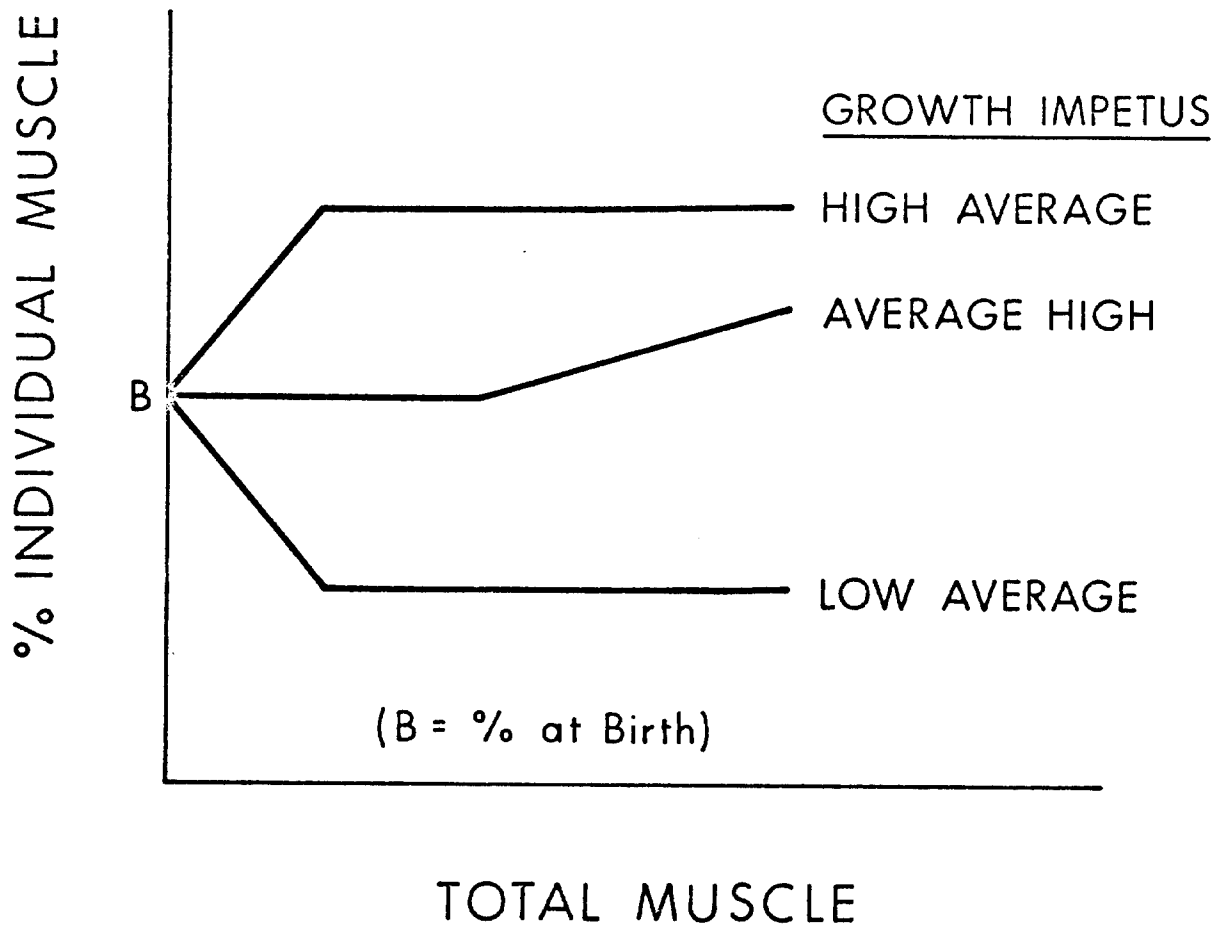

Figure 3:

Schematic Representation of Diphasic Muscle Growth Impetus Groups as a Percentage of Total Muscle.

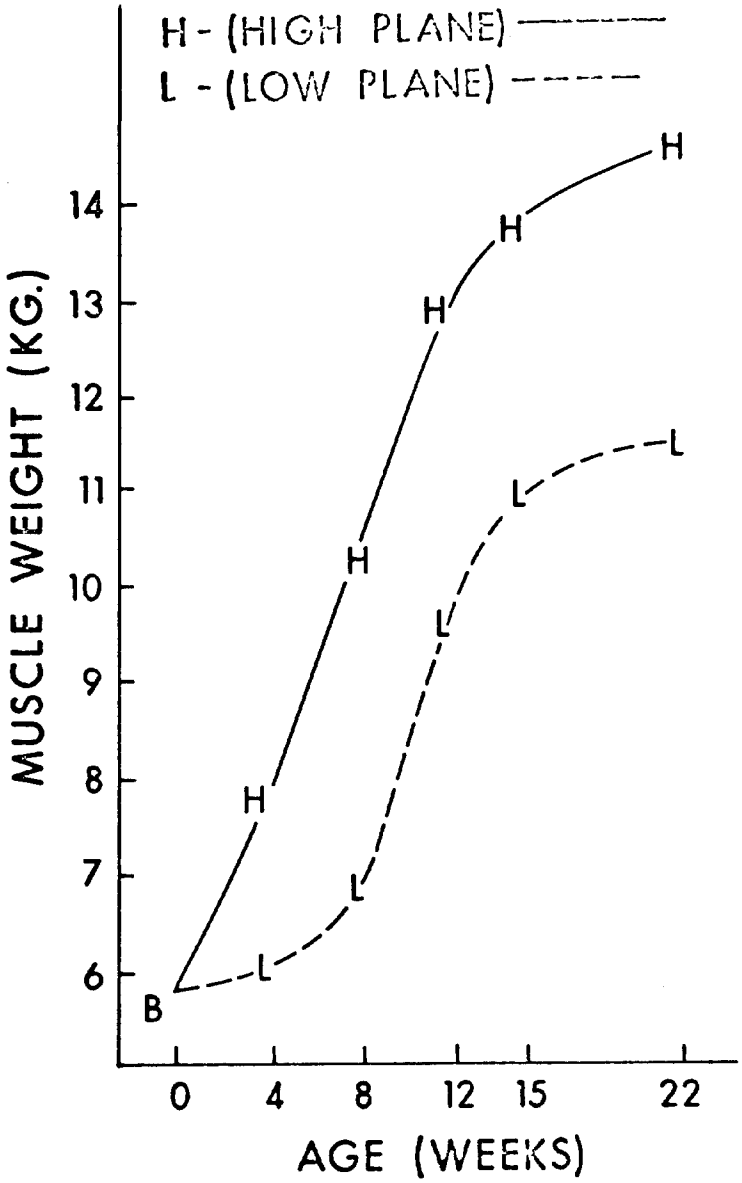

Fig. 4:
Muscle growth in calves fed two planes of nutrition (Berg and Butterfield, 1968).

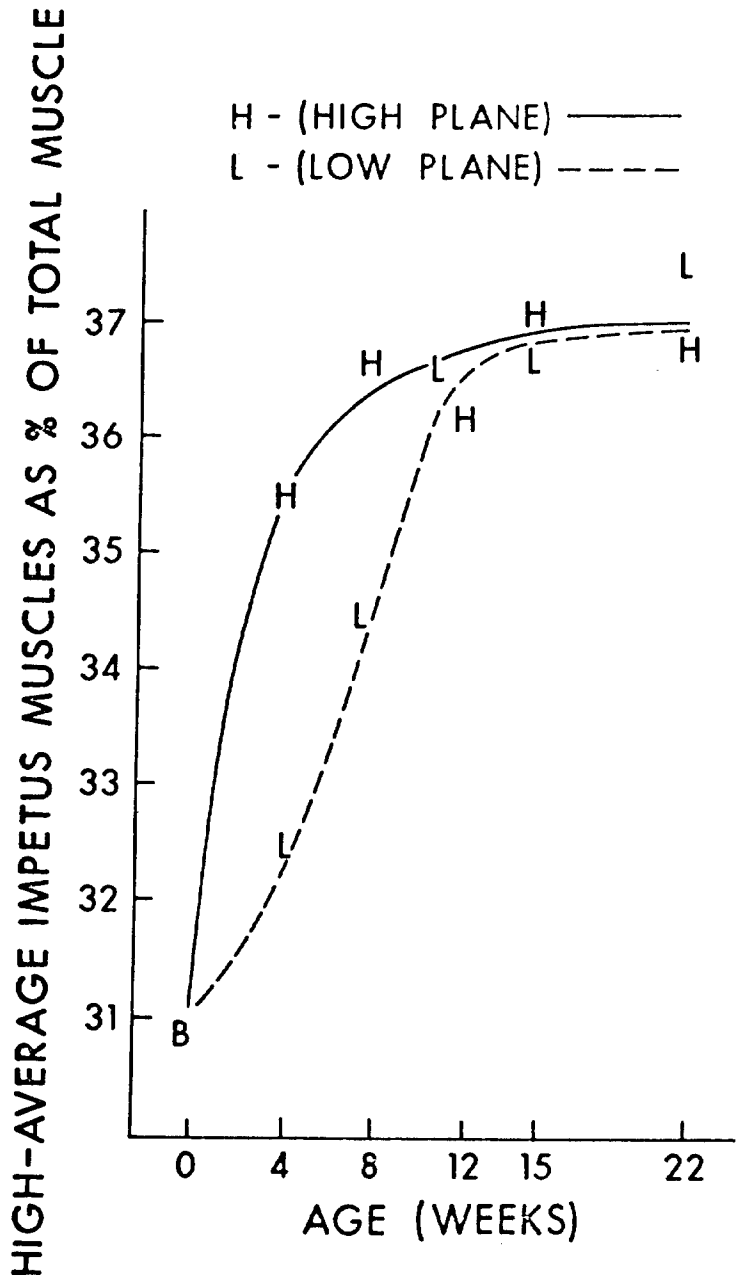

Fig. 5:

High-average impetus muscles as a percentage of total muscle in carcasses of calves fed two planes of nutrition (Berg and Butterfield, 1968).

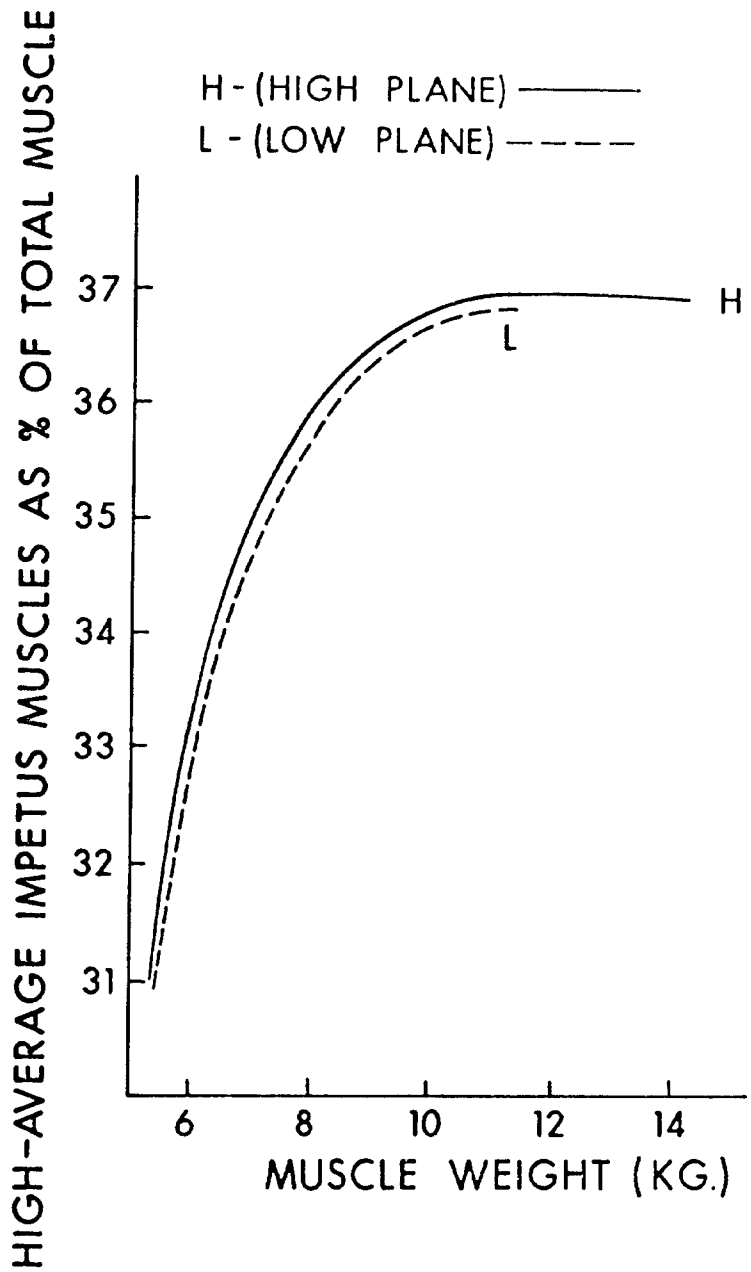

Fig. 6:

High-average impetus muscles as a percentage of total muscle in carcasses of calves fed two planes of nutrition (Adapted from Berg and Butterfield, 1968).

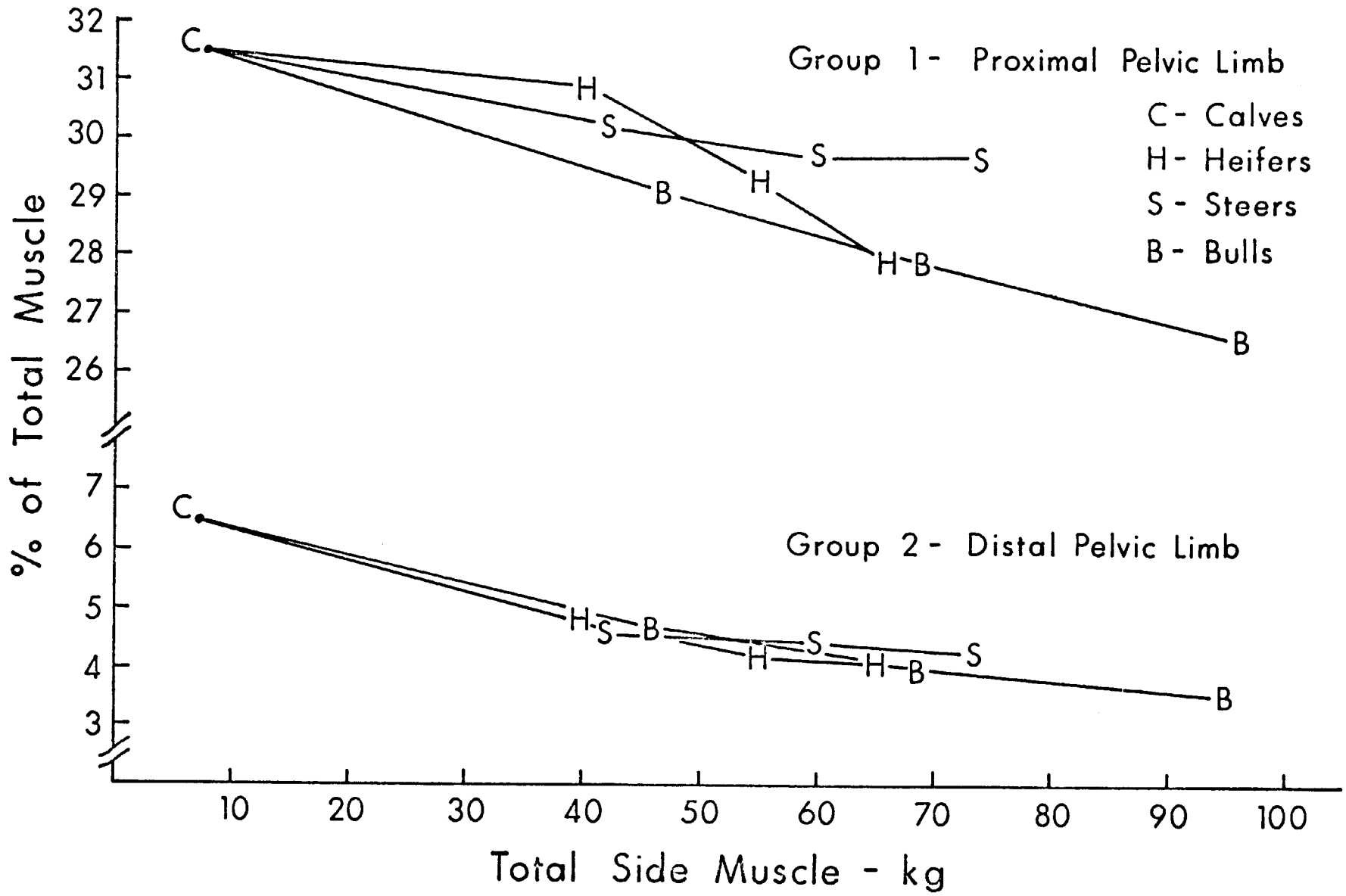

Figure 7: Percentage of Standard Muscle Groups 1 and 2 Relative to Total Muscle in Beef Carcasses.

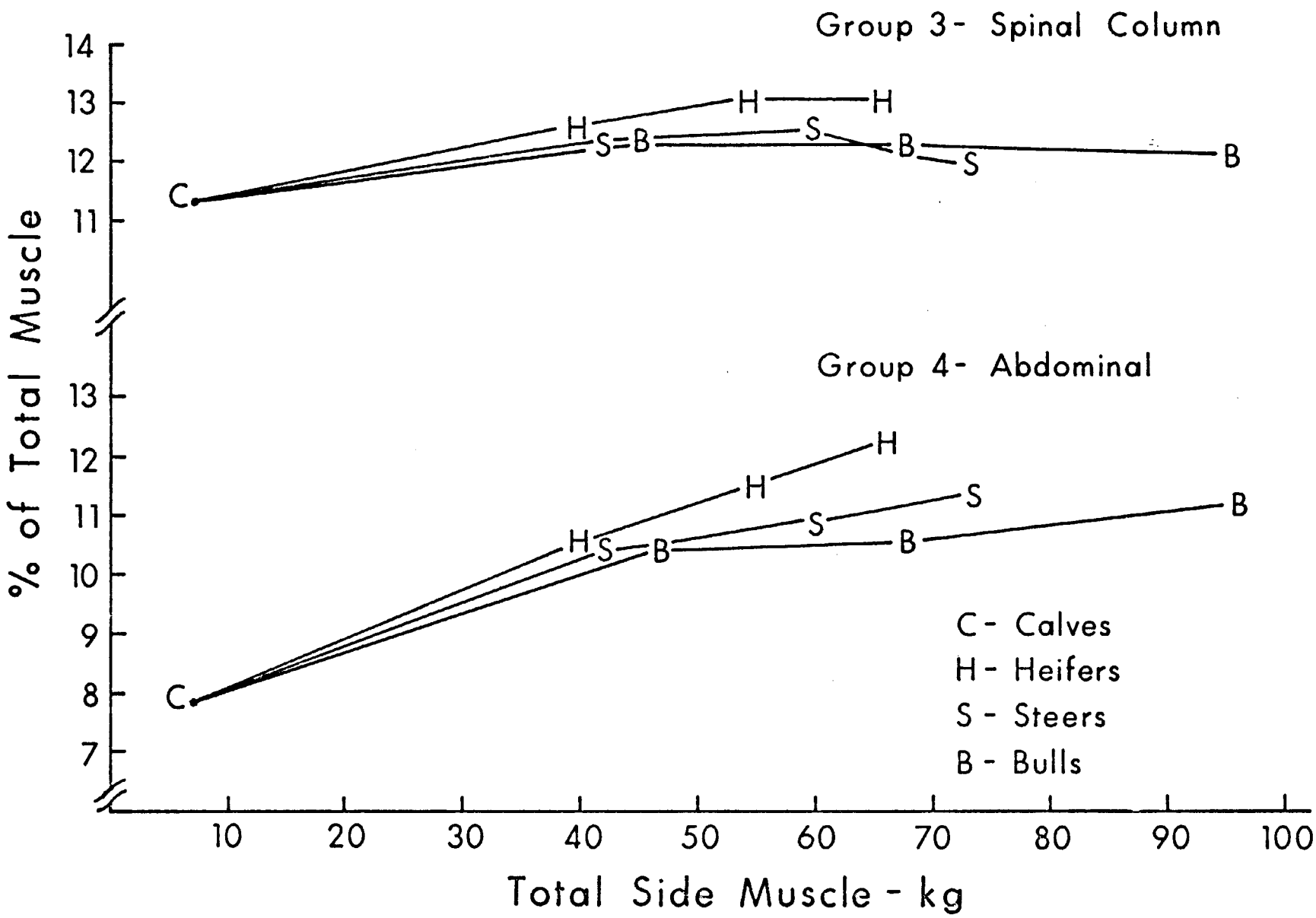

Figure 8: Percentage of Standard Muscle Groups 3 and 4 Relative to Total Muscle in Beef Carcasses.

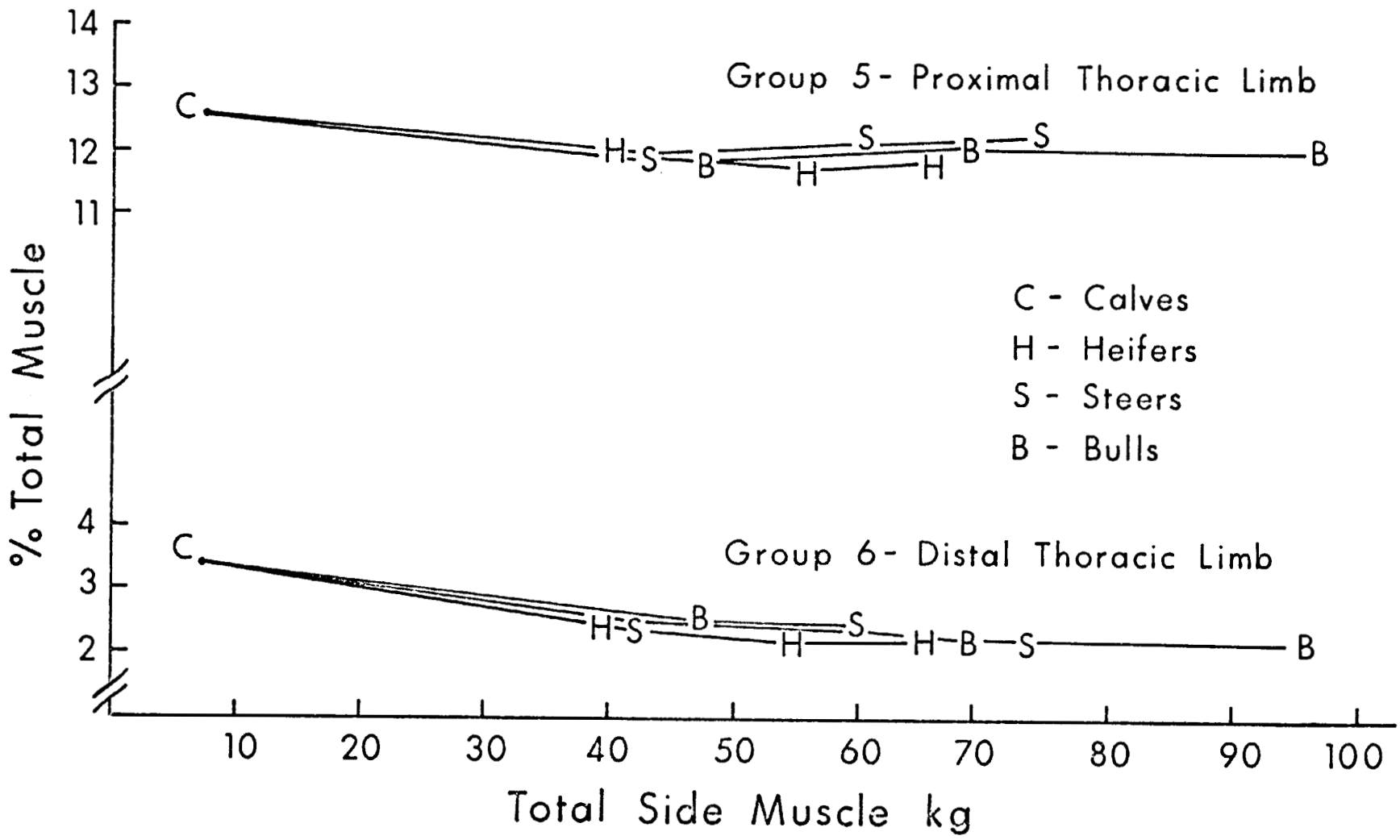

Figure 9: Percentage of Standard Muscle Groups 5 and 6 Relative to Total Muscle in Beef Carcasses.

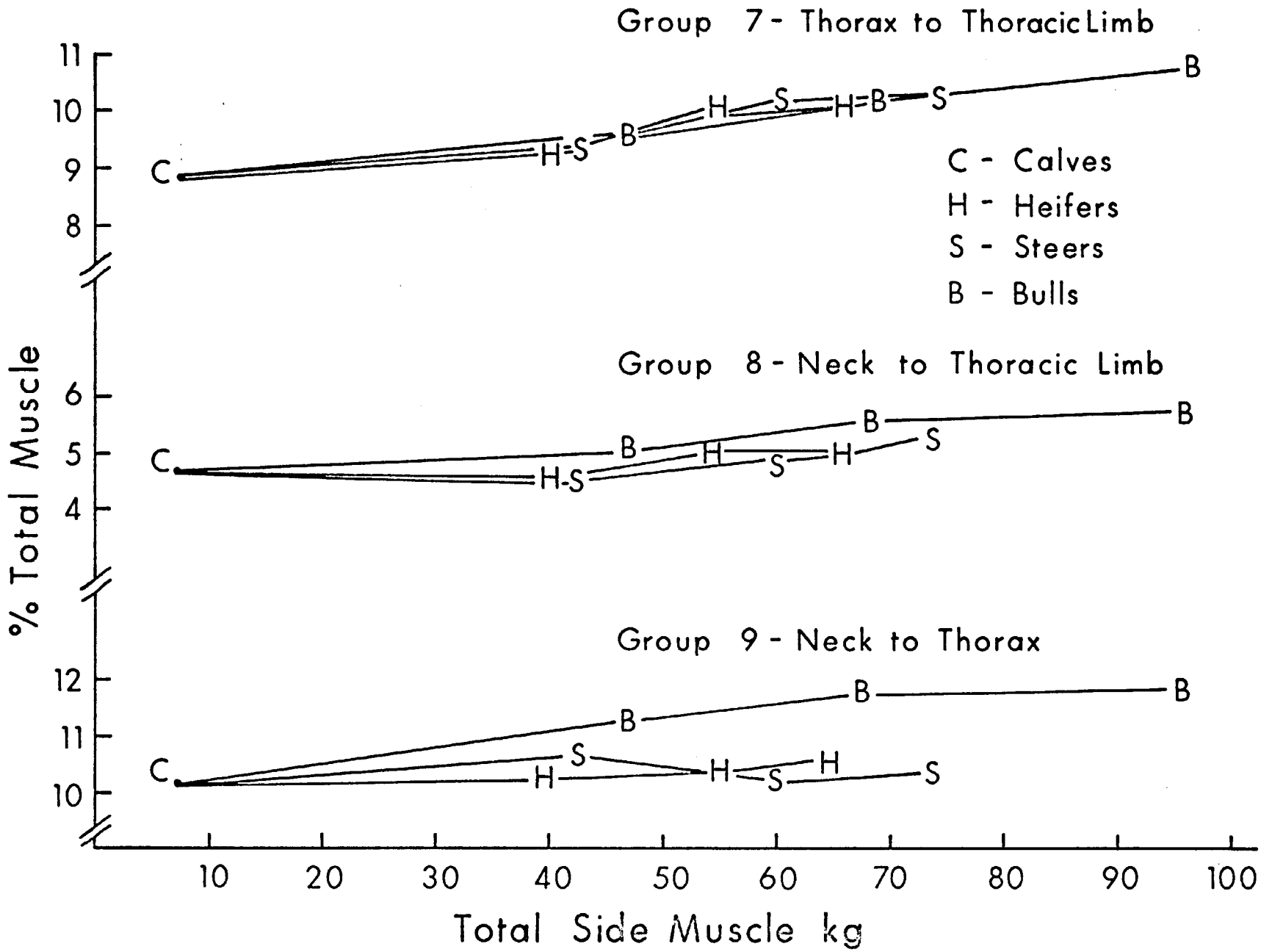

Figure 10: Percentage of Standard Muscle Groups 7, 8 and 9 Relative to Total Muscle in Beef Carcasses.

L. E. WALTERS: On behalf of the Committee and the Conference, I would like to say a special thank-you to the three speakers on our program, and we will now turn this over to Dale Zinn for the discussion.

D. W. ZINN: Thank you, Lowell.

I think the three papers which have been presented to us this afternoon should have raised a number of questions in our minds concerning the evaluation of carcass composition, the growth and development of the animal. They might still leave us room to think about the fact that while at the same weight, we may have similar composition in the animal, the age of the animals at which they reach that weight may be a very important factor as far as the economy of production of meat is concerned. I think that Dr. Berg indicated that he does not quite believe that all animals are of the same composition if of the same weight. I think that the papers have presented us a number of important things that we need to consider now or later, and I think it also indicates what was pointed out by one of the speakers, Dr. Caster, this morning, that we are going to have to learn an awful lot more about how the animal grows and develops and how the interaction of genetics and nutrition and environment and management influence growth and development if we are to continue to produce meat and protein for consumption in this world. I think Dr. Caster indicated this morning that we wouldn't be feeding grain to livestock too much longer. If we are, we are going to have to become much more efficient in doing so.

Do we have any questions from the audience? If you do, please speak up loud--there are some microphones spotted around that will pick it up. I understand I have about four minutes left for questions, so let's have them.

BOB KAUFFMAN from Wisconsin: This is directed to Dr. Reid, and I guess I am representing about 75% of the group that is here--I don't know about the other 25%. Just recently at our station, we looked at the composition of some carcasses on a rather routine rather negligible basis on the basis of your work. We only had 70 and you had hundreds. But I wonder if you could explain to me how we happened to find when we looked at the pig carcasses on a fat-free muscle basis that we were able to obtain as much as 10 kilograms difference in pigs of the same weight, and also another observation of about 55 cattle in which we obtained a coefficient of a little bit above zero between body weight and composition of the carcass.

J. T. REID: First let me clarify what appears to be a misconception which I hadn't recognized until Dr. Berg's comment. The context in which I am dealing and in which I feel quite confident in that with meat-producing animals we are dealing with relatively immature animals--we are dealing with pigs that don't weigh more than perhaps 250 pounds and cattle perhaps no larger than 1200 or so. We are dealing with relatively immature animals. Now another thing that I think can lead to misconceptions: that is when we are dealing with anatomical groups, if we are dealing with cuts, or dealing with separated fats from cuts, we are not really comparing separated fats to ether extracted fats nor are we comparing muscle to protein. On the chemical basis, they found no difference, and it was on this basis that I showed you their data. Most of the data I showed you are based on chemically analyzed substances, not physically separated. Now in some instances

I showed you some that were physically separated, but which were at the same time, chemically analyzed.

D. W. ZINN: Thank you, Dr. Reid for these additional comments. Do we have any other questions?

QUESTION: I'm Walt Kinnick from Oregon State. I would like to address a question to Richard Waldman. Did you hold age constant in your analysis? In other words, are you talking about a nutritional difference or an age difference?

RICHARD WALDMAN: I think that you are right in that we did not hold age constant in this analysis, but we haven't really gone too far in the analysis of this data. What you saw was just the first attempt to get it on some kind of logical setup, and I would say that age possibly is influencing the data on tests of this, and also that the highs were always fatter than the mediums and so we hope to come up with some of the explanations of why we do not find large differences in tenderness between all the animals of such varied age groups. These animals never were over 23 months of age. I don't know whether 23 months of age is going to affect tenderness or not, but it might; but this was analyzed with animals at all different ages.

D. W. ZINN: Thank you Dick. One more question.

DALE HUFFMAN: I am in sympathy with what Bob Kauffman has said here, but Dr. Reid I would like to ask you. Perhaps the fact that we are looking at only one component of the animal, rather than the entire animal, could cause some of the experiences here.

DR. REID: Yes, I think this is possible, especially if you only use one body part, say, a loin, and estimate the mean to the total body. So far, as accounting for this major difference, I'm not sure, because it is not really clear whether this is one part or whether it is one side, and as I pointed out there are some nutritional differences which have been described. The mere fact that we haven't found some doesn't mean that there aren't any.

D. W. ZINN: I think we could continue this discussion the rest of the afternoon, but they told me to cut it off in seven minutes, and it is that time. Please reassemble in here at three-thirty. Thank you.

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