

Anatomical Studies of the Growth of Carcase Muscles

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Introduction

I wish to dedicate this lecture to the memory of the late Dr. A.M. Pearson. Unfortunately, we never met. Dr. Pearson, whose longstanding contribution to this Association is recorded throughout many volumes of Reciprocal Meat Conference Proceedings, was extremely diligent in his sponsorship of my nomination for this 1999 AMSA International Award. For this I am deeply grateful as I am also grateful to AMSA for selecting me to be the recipient of this award and Protein Technologies International for their generous sponsorship.

It was because of Dr. Pearson's strong belief that growth and development of meat animals is the fundamental basis of Meat Science, that I have the privilege of sharing with you today some of the erratic progress which has marked our increase in knowledge of the gross anatomical aspects of muscle growth over the last seventy years. Bertrand Russell could well have been referring to our field of endeavour when he said: "Ascertainable truth is piece-meal, partial, uncertain and difficult." (Brody, 1945)

Many workers in many countries have contributed to our knowledge during this time, so in this brief presentation no attempt is made to review the full span of knowledge. Rather, I will be selective of those aspects most closely related to the work of my immediate associates whose efforts over many years make this presentation possible.

The Cambridge School

The results of studies of growth and development of meat animals started to emerge from the Cambridge (UK) school of John Hammond in the early 1930's although some of the anatomical dissections of legs of mutton by his collaborator, A.B. Appleton, date as far back as 1913. Hammond understood the need for an anatomical approach as is clear from his statement; "It is in experimental anatomy . . . that the solution of these (animal breeder's) problems will be found" (Hammond and Appleton, 1932).

Unfortunately, the Hammond School discarded the anatomical approach, possibly under real or perceived pressure to make the separation of the tissues more relevant to the butchering trade. As Pomeroy (1978), one of the Hammond's earlier students, made clear in an excellent review of growth and development, "Because the Cambridge workers all used essentially the same dissection technique, they all reached the same conclusions . . ."

Two of these conclusions were more the product of techniques than of anatomical structure, thus highlighting the unsuitability of these techniques as a basis for development of principles of growth within the musculature. The alleged "late development" of the "loin" (Hammond, 1940) was largely a feature of the muscles of the abdominal wall which were included in the "loin" cut. Therefore, the presumed advantages of using early maturing animals to gain maximum yield of desirable lumbar muscles were falsely based. Pomeroy (1978) stated: "In retrospect it must be admitted that the technique was peculiar in that it was neither based on an accepted commercial jointing system nor was it based strictly on the anatomy of the musculature." Even had it been based on a commercial jointing system, it would have still given misleading results regarding relative growth within the musculature.

It was Wallace (1948), a later student of Hammond, who threw doubt on one of the major conclusions of the earlier work. He questioned the finding that the relative size of muscles was affected by plane of nutrition and hence by growth rate of the animal.

Wallace was supported by the principle expounded by Huxley (1932), that there is an almost constant relationship between the weight of a part and the weight of a whole, at any particular stage of growth irrespective of the time taken to grow.

Wallace pointed out that in experiments such as those of McMeekan (1940), the nutritional treatments resulted in different proportions of fat and hence in different amounts of total muscle at any chosen carcase weight. Therefore, comparisons of relative proportions within the musculature at equal carcase weight were made at unequal total muscle weight. As the relative size of muscles varied between animals on different nutritional levels, it was concluded that this showed a nutritional effect. It later became clear that in comparisons at equal muscle weight the nutritional "effect" disappeared.

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These early workers were unfortunate that their experiments were based in the phase of growth when individual muscles grow at markedly different rates to each other.

Despite these problems, the Cambridge workers made very significant contributions to our early knowledge of the relative growth of the carcass tissues.

Muscle-Weight-Distribution of Cattle

It was almost thirty years after Appleton when an anatomist re-entered the field; not in search of principles of growth and development; but in an attempt to answer the burning question in the Australian cattle industry; "Will the strange-looking Brahman cattle which are entering our tick-infested areas cause the disastrous deterioration of body composition which has been predicted by most of our cattlemen?" These cattlemen had been reared to believe that only British beef cattle are real beef cattle.

We were not the first in Australasia to use a technique of total dissection of the musculature to study cattle, as a team in New Zealand headed by Daintree Walker (1963) was already dissecting Angus and Jersey cattle. We devised a less labour intensive technique than used in New Zealand, and dissected groups of Brahman and Poll Hereford cattle over the period of 1960-1963. It was soon apparent there was little difference between what came to be known as the "muscle-weight distribution" of Brahman and British beef cattle.

The results of this work were largely presented by comparison of the proportions of total muscle weight comprised by a set of regional groups of muscles designated as "Standard Muscle Groups" (Butterfield, 1963). However, for simplicity in extension to industry, we grouped the three major regions of the proximal parts of both limbs and the muscles surrounding the spinal column as the "Expensive Muscle Group."

Both the Brahmans and the Poll Herefords had 56% of their total muscle weight in the "Expensive" part of the carcass. The question was then raised; "If two modern breeds are so similar in muscle-weight-distribution; what is the situation in primitive cattle which have had little selection for beef characteristics? Has modern selection 'improved' muscle-weight distribution?"

Primitive cattle were not difficult to find at that time in Australia. We went to a property in Central Australia where they had introduced no new bulls for at least 70 years. The breeding program had been by survival of the fittest. We dissected a group of these cattle and came up with little difference from our modern breeds of Brahmans and Poll Herefords. The primitive cattle also had 56% of their muscle weight in the "expensive" parts of the carcass!

These results helped to settle the antagonism to the Brahmans, which were proving themselves more than a match for Australian ticks anyhow; and also to raise doubt about one of the primary criteria for show judging of beef cattle; the alleged differences in the relative size of muscles. However, we were extremely fortunate in our comparison of muscle-weight-distribution of breeds that our use of animals of various weights and nutritional histories did not prevent us from

reaching the conclusion that they varied little. This was possible because, as later revealed, muscle-weight-distribution in steers remains almost constant throughout the middle stages of growth.

These studies threw considerable doubt on the belief in the ability of man to alter the weight relationships within the musculature. Although McMeekan (1969) claimed later that knowledge of growth and development would allow us to "mould . . . composition of bone, muscle and fat in any desired direction," we were slowly becoming aware that the relative size of muscles had little to do with the desires of scientists, show judges, or the meat industry and was under the influence of much more powerful forces associated with survival and locomotion.

There are small differences in muscle-weight-distribution between animals and indeed breeds; but in normal cattle these are of minor economic importance. It is possible to select among "Double-Muscled" cattle for superior distribution of muscle weight (Shahin and Berg, 1985).

Muscle-Weight-Distribution of Other Species

Further studies of muscle-weight-distribution in the major meat species using our individual muscle dissection technique were undertaken in pigs by Richmond and Berg (1982) and in sheep by Lohse (1971) and Thompson (1983). The overall conclusion from these studies supported the concept of uniform muscle-weight-distribution within a species. The dissection technique, with some modifications to suit the variety of shapes, was used by Bryden (1967) on Elephant Seals; Hopwood (1976) on Kangaroos; and by Berg and Butterfield (1976) on individual animals from a range of species including Buffalo and Moose. These dissections established that each species has its unique muscle-weight-distribution.

Muscle Growth Patterns

It was apparent at this stage that we had an inadequate knowledge of how muscles grow. The Cambridge workers had been unfortunate to base their studies in that period of growth when muscles grow at a wide spectrum of rates. On the other hand, we had been lucky to make our comparisons of muscle-weight-distribution when differential growth was minimal. It was essential that we gained a better knowledge of the growth patterns of individual muscles and of regional groups of muscles.

The timely entry into our projects by Dr. R.T. Berg, a Canadian geneticist on sabbatical leave in Australia, inspired us to try to unscramble some of the mysteries of growth, and particularly growth of individual muscles and muscle groups. We needed a mathematical technique to develop growth patterns from the mass of data derived from our heterogeneous group of cattle. Despite the previous dismissal by Palsson (1955) of Huxley's concept of relationship of parts to the whole as being unsuitable for use in domestic animals, Berg soon appreciated the value of the allometric equation of Huxley (1932). This mathematical method formed the

basis of our first classification of muscle growth patterns (Butterfield and Berg, 1966 a,b).

Brody (1945) whose magnificent book *Bioenergetics and Growth* has done so much to inform us on a wide range of growth phenomena, had dismissed the use of the term 'allometry' in somewhat colourful language as being the product of "name-minded biologists" and "evocators," preferring to stick with the older "parabola." Whatever the name of the mathematical procedure, the result was a method which allowed us to develop muscle growth patterns from our mass of data.

However, we were confronted by the existing terminology, some of which we found incomprehensible. What did terms like "early maturing" and "late maturing" really mean?

We discarded these terms and described our muscle growth patterns according to their growth rate relative to that of total muscle. We classified muscle growth patterns according to "growth impetus," which was simply a measure of how fast a muscle grew relative to the growth rate of total muscle.

A "high impetus" phase of growth simply meant that the muscle was growing faster than total muscle. Similarly, "low" or "average" impetus related to the growth of total muscle.

Extension to Industry

To gain support from industry for our emerging studies of growth and development, it was essential to convince animal breeders that these studies could reveal information of value to them. Accordingly, a period of extension to industry of our quite primitive knowledge of growth and development was achieved by a large number of presentations to cattle breeders, particularly in North America and Australasia. The most memorable, an invited lecture in 1974 for the Bank of America at a California Livestock Symposium, under the title of "Exposing the Myths of Show Judging" (Butterfield 1975) led to a great deal of industry debate and a realisation that there was still much to be learned. Later, opportunities arose to present courses to South American scientists in Argentina and European scientists in Germany (in association with Dr. St. C.S. Taylor). The feed-back from these contacts was vital to the development of our ideas.

Unscrambling the Principles

Enthusiasm to more clearly define some of the major principles of growth in the musculature was now running high, and we looked at the affects of body weight loss and regain, an integral part of the growth pattern of many Australian beef cattle of that time. This experiment (Butterfield, 1966) showed the relative priority for nutrients of the carcass tissues, and of special interest, confirmed the functional basis of relative muscle size. The muscles least essential for survival lost the most weight during body weight loss and recovered most weight during regain to soon resume a "normal muscle-weight-distribution."

We were now sure that the relative size of muscles at any stage of life was achieved in anticipation of functional demands. We had seen how the relative size of muscles in the

drought-stricken animal was best arranged to ensure the survival of the animal. We saw a similar situation in the new born calf in which the primary muscles of locomotion are better developed than the remainder of the musculature. We were also aware that immediately following birth, while the animal approximately trebles its birth weight, there is a period of frenzied differential growth in the musculature to fit the animal for adolescent and adult life. Later in the maturing bull, there is rapid growth of muscles, particularly of the dorsal neck which are essential if the bull is to win the right to mate.

To test the affects of different levels of nutrition on muscle growth, we next fed calves of uniform genetic background to achieve extremely different growth rates. Then in a serial slaughter program, we compared the relative size of their muscles at similar ages and at similar total muscle weights.

Making use of knowledge of growth patterns of individual muscles, we were able to show that total muscle weight and not age was the determining factor in the relative size of muscles (Butterfield, et al., 1966; Butterfield and Johnson, 1971). As Taylor (1982) in a different context said: comparisons at "the same age are obviously a biological nonsense." It was also quite clear that equal carcass weight was an inappropriate basis on which to compare relative muscle weights because as variation in fatness resulted in variation in total muscle weight as Wallace had explained several years before.

The Maturity Concept

By this time we were becoming increasingly aware that our experimental and statistical methods were inadequate to assist us in gaining a deeper understanding of individual or regional muscle growth. The part being studied was often a considerable proportion of the whole to which it was being related, and as Brody (1945) had put it, "Common-sense considerations . . . indicate that the percentage change in one variable tends to vary directly with percentage change in a related variable." These factors added to the statement of Fitzhugh and Taylor (1971) that "at any given stage an animal will have as many degrees of maturity as it has traits which can be measured," highlighted the need for different methods of study. It was also clear that if we wished to make more accurate comparisons of the relative size of muscles in animals of different mature size, this would require those comparisons to be made at similar degrees of maturity.

Dr. St. C.S. Taylor and his group in Edinburgh, Scotland were enthusiastically promoting the need to look at growth data relative to mature size. An experiment in which they used dam size as an approximation of mature size (McClelland, et al., 1976) provided the stimulus for us to carry out a series of serial slaughter programs.

Our aim was to study the progress of each muscle and muscle group to maturity, relative to the progress of total muscle to maturity. The weights of each muscle, determined by serial slaughter and appropriate dissection, were converted to proportions of the mature weight of the muscle. These were

plotted against values for total muscle weight calculated in a similar fashion.

Dr. David Griffiths, an innovative statistician joined our team at this stage and developed the "Maturity Coefficient" which proved adequate to define the maturing pattern of most body tissues and certainly all muscles. As with the allometric coefficient used earlier, we were able to classify all the muscles according to growth impetus.

Because of their small size, sheep have been the subject of our maturity work (Butterfield, et al., 1983; Butterfield, 1988). We were able to make comparisons of different breeds and sexes, and place numerical values on the growth pattern of each muscle. Because the subject animals were of known genetic and nutritional history, we were able to achieve much greater precision than has so far been possible in cattle.

Commercial Boning Techniques

Earlier in this paper I was critical of the use of commercial boning room techniques in attempts to develop growth principles. This should not detract from the strictly controlled use of the boning room when developing commercial processes. Boning rooms can produce accurate, commercially relevant results. Recently in Australia we have been evaluating the use of VIAscan® in the prediction of saleable beef yield. It was necessary for this evaluation that we know the accuracy of the boning room process in producing "Saleable Beef Yield." Accordingly, we processed the right and left sides from 46 assorted cattle. The yield of saleable beef as a percentage of carcass weight varied by a mean of less than one percentage point between the sides.

While it is essential that we use strict anatomical methods to determine principles of growth, there are certain commercial situations where boning room data is not only sufficiently accurate, but also preferable because of its direct relevance to commerce.

Into the 21st Century

I would hope to see much wider use of anatomical techniques in the future as there is much to be learned of the principles of growth, particularly before and immediately after birth. We need a precise study of muscle growth in cattle as the current knowledge lacks the precision of that available on sheep.

By relating our gross anatomical knowledge of growth patterns of muscles to biochemical and histological changes, we will gain a much better appreciation of the qualities of individual muscles which may lead to better appreciation of their value in the market place.

In response to the major theme of this conference; "Adding Value to the 21st Century," I make a plea that the adding be done to the products from functionally efficient animals. As meat scientists, we should attempt to steer the animal production industries away from the perpetuation of functionally inefficient animals which make it difficult to promote the meat industries as being based on happy, healthy, functionally normal animals. There is no doubt an increasing need, not only to produce better meat, but to produce it in such a manner that consumers are happy to buy it.

References

- Brody, S. 1945. *Bioenergetics and Growth*. Hafner Publishing Co. New York.
- Berg, R.T.; Butterfield, R.M. 1976. *New Concepts of Cattle Growth*. Sydney University Press. Sydney.
- Butterfield, R.M. 1963. *A Study of the Musculature of the Steer Carcass*. Ph.D. Thesis. University of Queensland.
- Butterfield, R.M. 1966. The Effect of Nutritional Stress and Recovery on the Body Composition of Cattle. *Research in Veterinary Science* 7:168-179.
- Butterfield, R.M. 1975. Exposing the Myths of Show Judging. *Polled Hereford World* 29(7):124-127.
- Butterfield, R.M. 1988. *New Concepts of Sheep Growth*. University of Sydney. Sydney.
- Butterfield, R.M.; Berg, R.T. 1966a. A Classification of Bovine Muscles based on their Relative Growth Patterns. *Research in Veterinary Science* 7:326-332.
- Butterfield, R.M.; Berg, R.T. 1966b. Relative Growth Patterns of Commercially Important Muscle Groups in Cattle. *Research in Veterinary Science* 7:389-393.
- Butterfield, R.M.; Griffiths, D.A.; Thompson, J.M.; Zamora, J.; James, A.M. 1983. Changes in Body Composition Relative to Weight and Maturity in Large and Small Strains of Australian Merino Rams. 1. Muscle Bone and Fat. *Animal Production* 36:29-37.
- Butterfield, R.M.; Johnson, E.R. 1971. A Study of Growth in Calves 2. Relative Growth in muscles. *Journal of Agricultural Science* 76:457-458.
- Butterfield, R.M.; Pryor, W.J.; Berg, R.T. 1966. A Study of Carcass Growth in Calves. *Research in Veterinary Science* 7:417-423.
- Bryden, M.M. 1967. *The biology of the Southern Elephant Seal; Development and Growth*. Ph.D. Thesis. University of Sydney.
- Fitzhugh, H.A.; Taylor, St.C.S. 1971. Genetic Analysis of Degree of Maturity. *Journal of Animal Science* 33:717-725.
- Hammond, J. 1940. *Farm Animals*. Edward Arnold and Co.; London.
- Hammond, J.; Appleton, A.B. 1932. *Growth and the Development of Mutton Qualities in the Sheep*. Oliver and Boyd. Edinburgh.
- Hopwood, P. 1976. *The quantitative Anatomy of the Kangaroo*. Ph.D. Thesis. University of Sydney.
- Huxley, J.S. 1932. *Problems of Relative Growth*. Methuen; London.
- Lohse, C.L. 1971. *Studies in the Quantitative Anatomy of Merino Sheep*. Ph.D. Thesis. University of Sydney.
- McClelland, T.H.; Bonaiti, B.; Taylor, St. C. S. 1976. Breed Differences in Body Composition of equally Mature Sheep. *Animal Production* 23:281-293.
- McMeekan, C.P. 1940. Growth and Development in the pig with special reference to carcass quality characters. *Journal of Agricultural Science* 30:276-343.
- McMeekan, C.P. 1969. *Science and World Animal Production*. Sir John Hammond Memorial Lecture, Sir John Hammond Memorial Trustees and The British Society of Animal Production.
- Palsson, H. 1955. *Progress in the Physiology of Farm Animals*. Vol 2. Butterworths London.
- Pomeroy, R.W. 1978. Historical and General Review of Growth and Development, in *Patterns of Growth and Development in Cattle*. Ed. H de boer; J. Martin. Martinus Nijhoff. The Hague. pp 3-11.
- Richmond, R.J.; Berg, R.T. 1982. Relative Growth Patterns of Individual Muscles in the Pig. *Canadian Journal of Animal Science* 62:575-586.
- Shahin, K.A.; Berg, R.T. 1985. Growth and Distribution of Individual Muscles in Double Muscled and normal cattle. *Journal of Agricultural Science* 105:479-490.
- Taylor, St. C.S. 1982. Theory of growth and feed efficiency in relation to maturity in body weight. 2nd World Congress on Genetics applied to Livestock Production 5:218-230.
- Thompson, J.M. 1983. Feed intake, growth and body composition in flocks of Merino sheep selected for high and low weaning weight. Ph.D. Thesis. University of Sydney.
- Walker, D.E. 1963. Age changes in the Carcass Composition of Aberdeen Angus Steers, Unpublished presentation. Symposium: Carcass Composition and Appraisal of Meat Animals.
- Wallace, L.R. 1948. The Growth of Lambs before and after birth in relation to the level of nutrition. *Journal of Agricultural Science* 38:243-302.