GENETIC AND ENVIRONMENTAL FACTORS INFLUENCING GROWTH OF MUSCLE AND FAT TISSUE

Factores genéticos y de medio ambiente que influyen sobre el crecimiento de los tejidos muscular y adiposo

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As an animal grows, besides an increase in weight, there are associated adjustments in the relative proportion of component parts. In meat animal species the carcass represents an important point in the economic production process and its composition (the proportion of the major tissues – muscle, fat and bone) largely determines carcass value. A high proportion of muscle with a low proportion of bone and an optimum level of fatness represents a carcass of superior merit.

Factors which influence growth patterns of muscle, fat and bone affect final composition. Major effects on carcass composition are known to be exerted by differences in slaughter weight, sex, breed-type and plane of nutrition. An understanding of growth patterns of the major carcass tissues and of factors which influence these patterns should assist producers to control the processes leading to a more desirable final carcass composition.

Slaughter Weight Influences

Muscle relative to bone in a normal calf at birth may be in the order of 2:1 whereas at a slaughter weight of approximately 500 kg., the ratio may be 5:1. Thus muscle has a much faster relative growth rate than bone. Fat growth starts out relatively slowly and increases somewhat geometrically as the animal enters a fattening phase. In very fat animals there may be more fat than muscle in the carcass.

Sex Influences

Heifers fatten earlier and faster relative to their live weight than do steers and steers fatten earlier and faster than bulls. At equal weights of muscle and bone the three sexes do not differ materially in muscle:bone ratios. Bulls in practice usually have higher muscle:bone ratios than the other sexes but this is probably a result of their heavier muscle weight partly because of less fat at any given market weight. Bulls are able to develop further than steers or heifers growing more muscle and bone before the fattening phase becomes pronounced.

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Breed Type Influences

Breeds can be classified into various maturity types depending on their expected fattening pattern. The British beef breeds (Shorthorn, Angus and Hereford) tend to be early maturing (early fattening) and the Continental European beef breeds tend to be late fattening. Breed differences are also found in muscle to bone ratio as reflected in light muscling (eg. Holstein-Friesan), heavy muscling (eg. Limousin or Blonde d'Aquitaine), “Double” muscling (Belgian Blue or Piemontese), is simply a condition of extreme heavy muscling.

Plane of Nutrition Effects

Energy consumption also influences the fattening pattern. A high energy ration and ad lib feeding results in earlier fattening; a low energy ration or restricted feeding causes later or delayed fattening. Generally increased percentage of roughage in a ration results in decreased percentage of fat in the carcasses.

Muscle Growth and Development

Muscle weight distribution in cattle has been studied by dissecting and weighing individual muscles from carcasses representing a range of ages from calves to mature cows and bulls. Animals from different sexes, breeds, and nutritional treatments have been subjects of these studies. From this research it has been possible to describe the normal changes which occur as a calf grows, develops, and eventually matures and to determine how important genetics and nutrition are to muscle weight distribution.

Normal Development of Muscle

Muscles respond to functional demands during growth and development, resulting in differential growth and changes in muscle distribution as measured by the relative proportions of different muscles and muscle groups. Birth initiates perhaps the greatest adjustment. An evolutionarily acquired genetic pattern occurring before birth equips the newborn calf with well developed muscles of the distal limbs to assist in minimum locomotion to find his first meal and strong muscles of the jaws to extract it. Marked changes occur soon after birth, with the large muscles of the hind limb developing along with improved locomotion. Later when the calf starts to take roughage feed the muscles of the abdominal wall increase as support for the gut and its contents. Little further change in muscle weight distribution is seen until puberty is passed when the young male enters a maturing phase which adapts the musculature to the dual role of survival.
and reproduction — more particularly reproductive competition. Success in gathering a harem of females is related to increased proportions in neck and shoulders associated with success in battle or bluff in a dominant male. Some adjustment in weight support occurs in a relative shift forward of muscle weight to accommodate these maturity changes.

Sex Influences on Muscle Distribution

The pattern of muscle growth emerges as an evolutionarily acquired genetic pattern before birth, modified by functional demands following birth. Then follows a post-pubertal adolescent phase, during which relative weights of muscles change little, from which heifers do not emerge and steers show a faint image of the changes which occur following puberty in a young bull when marked changes in muscle weight distribution result in a shift to neck and shoulders (Butterfield and Berg, 1972).

Breed Differences in Muscle Distribution

Butterfield (1965) reported dissection data from 6 breeds of steers and demonstrated a similarity of proportions of muscles in different regions. Extensive studies of a number of breeds since have failed to reveal differences in muscle distribution of a magnitude to be commercially important. There is a high degree of uniformity among breeds in muscle weight distribution, and although some differences have been statistically significant, they have been rather small and seem to be related to maturity type (Berg, Andersen and Liboriussen, 1978).

Although maturity status may account for much of the observed differences in muscle distribution, it seems entirely probable that mature muscle weight distribution would show some variance between breeds of very different size, skeletal development, and muscle-to-bone ratios. Berg and Butterfield (1976) noted that smaller species tended to differ in muscle weight distribution from larger species, differences which may be related to relative demands on weight support muscles. Skeletal differences such as length of leg could also introduce functional differences in muscle distribution.

Study of some other species of animals has helped to understand muscle weight distribution and what might be involved if we hope to change muscle distribution. Nine species were compared to cattle for muscle proportions by Berg and Butterfield (1976). It appears that the smaller the species, the more likely it is that an increased proportion of its muscle will be concentrated around its spinal column, with a correspondingly lower proportion required for weight support. The more agile the species, the more muscle in the distal parts of the limbs; the
more mobile, the greater the proportion in the whole of the limbs. Domestication of animals appears to have brought about an increase in muscles of the abdominal wall to cope with a more continuously fully loaded digestive tract. Male dominance, fighting behavior, and the development of an impressive profile (bluff selection) probably influence species-specific muscle distribution in the mature male.

In general we can now conclude that there are genetic differences in muscle weight distribution among breeds at standard muscle weights; that these differences, although they may be statistically significant, are rather small, and that breed differences that exist probably reflect maturity type and minor functional influences resulting from differences in size, shape, skeletal dimensions, and muscling. Functional needs of the species seem to have resulted in an optimum muscle-weight distribution which is relatively predictable in cattle and probably in other species as well. Under the influence of man only small changes in muscle weight distribution have occurred among cattle breeds.

Other Factors and Muscle Distribution

Rate of growth, at least within reasonably wide limits, does not seem to change the normal patterns of muscle distribution changes when they are viewed relative to total muscle growth. Bulk content of the ration and feeding ad lib may elicit a response in abdominal muscles.

Exercise differences as between pasture and stall rearing do not seem to cause any departure from normal muscle proportions. The potential for changing muscle weight distribution by abnormal or excessive exercise has not been demonstrated in cattle. However, Gunn (1975) demonstrated differences in muscle-weight distribution in Thoroughbred horses and Greyhound dogs, both bred for racing, compared to other breeds within their respective species.

Fat Partitioning and Distribution

Partitioning of fat was referred to by Callow (1948) to describe its location within the various depots (i.e. subcutaneous, intermuscular, etc.), whereas distribution of fat refers to its location within the depots. Beef carcass value is influenced by both amount and distribution of fat. A number of studies have shown that the partitioning of fat among the depots is influenced by slaughter weight and breed. It was demonstrated by Callow (1948) and confirmed by others since that fat depots grow differentially with subcutaneous (SCF) fat having a higher impetus than intermuscular (IMF) fat. Kempster (1980) in a review, concluded that the relative growth of kidney
knob and channel fat (KKCF) is less predictable. However in cattle which are fattening KKCF appears to grow more rapidly than IMF.

Breeds that tend to fatten early and heavily (eg. Hereford or Angus) usually have been shown to have a higher SC/IM ratio than late and light-fattening breeds such as some dairy breeds (eg. Friesian) and large continental breeds (eg. Charolais) (Lister, 1976).

Berg and Butterfield (1976) suggested that fat partitioning and distribution might be related to local pressures that develop with growth. Thus the body cavity and IM depots show little resistance in young animals and as they fill, increasing resistance is encountered, causing more of the surplus energy to be stored under the skin as SC fat. Muscles and body shape create variable pressures, with the large fleshy muscles of the hindquarters causing more resistance to IM deposits than the flatter looser muscles of the thorax and neck, resulting in a shift of IM fat proportion forward with increased fattening. SC depots expand under the skin in less resistant areas (i.e. flank, twist, brisket, and anterior and posterior to the shoulder), gradually resulting in the overall smoothness characteristic of very fat animals. These theories seem more compatible with fat distribution than with fat partition among the depots.

In a Danish crossbreeding study, sire breed groups were compared with respect to growth patterns and distribution of fat (IMF and SCF combined) in various joints (Berg, Andersen, and Liboriussen, 1978a). With increasing slaughter weight the proportions of fat in the distal limbs, the round, and loin dropped noticeably; the proportions in the rib, flank, and brisket rose; and the proportions in the shoulder, fore rib, and neck showed little change. Interestingly all sire breed groups followed similar patterns of fat distribution as total fat increased. These results seem to indicate that difference in fat distribution among breeds is a natural result of some groups being fatter than others, and at the same total fat weight, differences are minor. Statistically significant sire breed differences were found for fat in most joints at a fixed level of total fat but these differences were relatively small and unimportant.

Allen and McCarthy (1980), studying the effects of selection for High and Low body weights at fixed ages in mice found that High and Low lines had differences in fat partitioning among the depots at fixed ages, at fixed body weights and at fixed weights of fat. At low body weights fat deposition was retarded in High compared to Low lines and since depots develop at different rates this led to different fat partitioning at equal weights. High selection seemed to exert a preferential effect on faster growing depots resulting in differences at equal weights of
These results indicate that further studies with commercial meat animals must be done to elucidate the biological reasons for observed differences in fat partitioning.

Summary

Superior carcasses yield a high proportion of muscle, a low proportion of bone and sufficient fat to satisfy local market requirements. Studies of growth of muscle, fat and bone indicate that fat is the most variable tissue and has the greatest influence on carcass composition. For a given animal of a certain breed and sex, muscle and bone follow fairly predictable relationships with growth. Control of carcass composition is mainly concerned with control of fat deposition. Factors which promote higher proportions of fat are: heavy slaughter weights; sex—with heifers being fatter than steers and steers fatter than bulls; breed—with early fattening breeds having higher proportions of fat; and high energy or ad lib feeding systems.

Breed differences are sometimes pronounced for fat partitioning among the depots but seem to have little influence on fat distribution.

The amount of muscle relative to bone is strongly under genetic control but there seems to be little scope for controlling the proportions of high priced retail cuts. Muscle develops under the influence of functional requirements and the pattern followed by different breeds though not identical is quite similar.

RESUMEN

Las canales de alta calidad aportan una elevada proporción de músculo, una baja proporción de hueso y suficiente grasa para satisfacer los requisitos de los mercados locales. Los estudios sobre el desarrollo del músculo, de la grasa y del hueso indican que la grasa es el tejido más variable y el que tiene mayor influencia sobre la composición de la canal. Para un animal dado, de una cierta raza y sexo, el músculo y el hueso siguen relaciones predecibles con el crecimiento. El control de la composición de la canal se refiere fundamentalmente al control de la deposición de grasa. Los factores que promueven proporciones más elevadas de grasa son: el elevado peso al sacrificio; el sexo (las novillas) son más grasas que los novillos y estos últimos más que los toros; la raza (con razas de engorde precoz que tienen una mayor proporción de grasa, y los sistemas de alimentación de alta energía o ad libitum).

Las diferencias raciales son a veces pronunciadas para el acumulo de los depositos de grasa, pero parecen tener poca influencia en la distribución de la misma.
La cantidad de músculo en relación con el hueso está bajo fuerte control genético pero parece constituir un pequeño objetivo para controlar las proporciones de los despieces de alto valor. El músculo se desarrolla bajo la influencia de las necesidades funcionales y los rasgos exhibidos por diferentes razas aunque no idénticos son bastante similares.

References