MUSCLE: HOW MUCH DO WE NEED? EFFECTS ON GROWTH, REPRODUCTION AND MATERNAL ABILITY

David S. Buchanan
Animal Science Department
Oklahoma State University

The selection history in purebred livestock has been characterized by cycles of emphasis on various dimensional characteristics. These cycles usually began with an interest in correcting a substantial shortcoming in the livestock in existence. For example, emphasis on increased frame size in cattle came along at a time when there were too many cattle with insufficient frame to efficiently produce a lean, high quality carcass. Similarly, the emphasis in the swine industry on leanness and muscling that began 30 to 40 years ago was dictated by a prevalence of lard-type pigs in the industry at a time when the value of lard declined rapidly.

These initial good intentions produced needed changes as people recognized the need for change and identified those individuals with the desired attributes. Unfortunately, single minded selection programs may lead to dedication to extremes. This state of affairs precipitated the need for this conference. In addition, dedication to extremes has frequently lead to a biological backlash by the animals involved. Extreme emphasis on compact cattle may have been behind the problems with dwarfism in some breeds. Even though it was never clearly identified, many observers felt that carriers of dwarfism had some visual quality that lead to their selection more frequently than non-carriers. In similar fashion, extreme emphasis on leanness in swine resulted in an increased incidence of stress syndrome and its associated problems with meat quality and productivity. In this case, there was a clear advantage in leanness of the carriers of the stress gene. We may be seeing a similar pattern in the sheep industry with the current problems with spider syndrome and its possible relationship to extreme emphasis on height. It appears that genetically altering one aspect of development without adequate attention to the overall well being of the animal will ultimately lead to a revolt by Mother Nature.

Current attitudes suggest that improvement in muscling and leanness is in order in the beef industry. This is dictated by several forces, not the least of which is the move toward specification programs by many of the major beef packers. Perhaps this is an opportune time for a change since extreme emphasis on height has not (yet?) lead to the types of substantial genetic problems outlined previously. The purpose of this paper is to predict the types of changes in productivity traits that will occur as a result of emphasis on muscling and leanness.

Correlated Genetic Change. Genetic change in many traits is fairly easy to achieve, although the process is fairly slow in beef cattle because of the low reproductive rate and long generation interval. All that is needed is an accurate evaluation of the trait in question and a willingness to choose only superior individuals as replacements. Careful evaluation of several items needs to be considered

when choosing traits to include in a selection program. The first item is the economic importance of the trait. Selection pressure is a precious commodity, especially in cattle, and should not be squandered on traits that do not contribute to efficient production. The heritability of the trait is also important. Heritability is a measure of the relationship between phenotype and genetic merit. As such, it provides an indication of the ease with which genetic progress can be obtained. Ease of measurement is a third consideration. Some traits may be important economically, but the expense of measurement outweighs the advantages to be gained by using them as a selection criteria. The last consideration is the relationship between traits. If traits have a genetic relationship, we must consider those relationships when designing selection programs.

Genetic relationships exist if genes control more than one characteristic. These relationships are measured with the genetic correlation. As a correlation, it may have values between -1 and +1. A genetic correlation with a high absolute value indicates that selection for one trait will cause large changes in another trait. A genetic correlation near 0 indicates little relationship and little response in the second trait due to selection pressure on the first trait. These relationships may be favorable or unfavorable. For example, selection for increased yearling weight leads to increases in weaning weight. It will also lead to increased birth weight and an accompanied increased incidence of calving difficulty. Correlated changes such as these must be considered when selection objectives are established.

The selection criterion to be considered in this discussion is muscling. The previous paper included information on correlated changes in other carcass characteristics. This discussion will center on the effect that selection for increased muscling will have on growth, reproduction and maternal ability. Three major points will be included: evidence on these genetic relationships from breed comparisons, the effects of selection of heavily muscled individuals within breeds and the ultimate problems that may arise if muscling is emphasized too extensively.

Breed differences. Part of the selection process involves choosing appropriate breeds for a particular crossbreeding system. The entire complex of traits must be considered when a breed is chosen. Each breed has distinct characteristics and will bring a different set of advantages and disadvantages to the commercial beef producer. The most extensive breed comparison study to date is the Germ Plasm Evaluation Project at the U.S. Meat Animal Research Center in Clay Center, Nebraska. A recent review of this project appeared in the Proceedings of the 3rd World Congress on Genetics Applied to Livestock Production (Cundiff et al. 1986). They summarized the results with a table of general comparisons which is shown here in table 1.

Table 1. Breed crosses grouped in biological type on the basis of four major criteria[a]

Breed Group	Growth Rate & Mature Size	Lean to Fat Ratio	Age at Puberty	Milk Production
Jersey	X	X	X	XXXXX
Hereford-Angus	XX	XX	XXX	XX
Red Poll	XX	XX	XX	XXX
Devon	XX	XX	XXX	XX
South Devon	XXX	XXX	XX	XXX
Tarentaise	XXX	XXX	XX	XXX
Pinzgauer	XXX	XXX	XX	XXX
Brangus	XXX	XX	XXXX	XX
Santa Gertrudis	XXX	XX	XXXX	XX
Sahiwal	XX	XXX	XXXXX	XXX
Brahman	XXXX	XXX	XXXXX	XXX
Brown Swiss	XXXX	XXXX	XX	XXXX
Gelbvieh	XXXX	XXXX	XX	XXXX
Holstein	XXXX	XXX	XX	XXXXX
Simmental	XXXXX	XXXX	XXX	XXXX
Maine-Anjou	XXXXX	XXXX	XXX	XXX
Limousin	XXX	XXXXX	XXXX	X
Charolais	XXXXX	XXXXX	XXXX	X
Chianina	XXXXX	XXXXX	XXXX	X

[a] more X's are associated with more rapid growth, higher lean to fat ratio, later age at puberty or higher milk production

Those breeds with higher lean to fat ratio (more muscling) tended to have higher growth rate and mature size. The relationships with age at puberty and milk production are less clear. The breeds with extremely high lean to fat ratio (Limousin, Charolais and Chianina) generally showed later age at puberty and lower milk production. This has lead some to conclude that the relationship between muscling and these "female" traits is strong and undesirable. However, breeds such as the Gelbvieh, Simmental and Maine-Anjou had fairly high lean to fat ratio and were average, or better than average, for age at puberty and milk production. Comparison of breeds does not lead to a clear understanding of the relationships among these traits. The choice of breeds should be made with an understanding of the relative merits of the breeds and an awareness of the selection history in each of the breeds under consideration.

Relationship between muscling and growth. Selection for increased muscling should be expected to have an impact on growth rate since the ratio of lean tissue to fat tissue should change and lean and fat are not added with equal efficiency. There have been several studies investigating the correlation between growth and carcass merit. Three of the more important investigations have been those of Cundiff et al (1971); Dinkel and Busch (1973) and Koch et al (1982). The first of these used data from the Hereford, Angus, Shorthorn crossbreeding project at Ft. Robinson, Nebraska. Some of the results are presented in table 2. Carcass weight at a constant age was their measure of growth performance.

Table 2. Genetic correlations between carcass weight and measures of carcass composition (from Cundiff et al, 1971).

	Correlations		
	fat thickness	rib eye area	Cutability
carcass weight at constant age	.34	.66	-.33

Dinkel and Busch (1973) evaluated Hereford steers reared in private herds in South Dakota. These results are presented in table 3.

Table 3. Estimates of genetic correlations between growth and carcass merit in Hereford steers (from Dinkel and Busch, 1973).

	Correlations			
	muscling score	rib eye area	fat thickness	Cutability
feedlot daily gain	.26	.49	-.25	.50
final weight	.24	.54	-.56	.74

Koch et al (1982) obtained within breed correlations from 2453 steers by 16 sire breeds in the US MARC Germ Plasm Evaluation Project. These results are presented in Table 4.

Table 4. Estimates of genetic correlations between growth and carcass merit in steers from several breed groups (Koch et al, 1982).

	retail product %	fat thickness	rib eye area
birth weight	.05	-.27	.31
feedlot daily gain	-.13	.05	.34

These studies were in general agreement that selection for increased rib eye area should lead to an increase in weight at a given age and rate of growth. The results from Koch et al (1982) also suggest that selection for increased muscling will result in an increase in birth weight. This would be expected to lead to increased incidence of calving difficulty.

A long term selection study has been conducted at Ft. Robinson and Clay Center, Nebraska (Buchanan et al, 1982a,b). The study involved Hereford cattle and included lines selected for 1. increased weaning weight, 2. increased yearling weight and 3. larger values of an index that included both yearling weight and muscling score. Results indicated that direct response to selection for yearling weight may be enhanced by inclusion of muscling score.

It can be concluded that, if muscling can be accurately measured, selection for increased muscling will not have a detrimental effect on rate of growth. In fact, if used in conjunction with selection for increased growth rate, it may aid in genetic evaluation of growth potential.

Relationship between muscling and cow traits. The literature base concerning the relationship between carcass characteristics and reproduction or maternal ability is quite small. One rather large study was conducted using cattle from seven breeds in the Germ Plasm Evaluation Project (MacNeil et al, 1984). Data from approximately four female and five male progeny each of 187 sires were used to investigate the correlations between carcass traits in steers and reproductive and maternal traits in their half-sib sisters. Some results are shown in table 5.

Table 5. Estimated genetic correlations between growth and composition traits measured on steers and reproduction and productivity traits measured on female half-sibs.

	Male traits			
female traits	postweaning daily gain	carcass weight	fat trim	retail product
age at puberty	.16	.17	-.29	.30
weight at puberty	.07	.07	-.31	.08
conceptions/service	1.33	.61	.21	.28
gestation length	-.10	.03	-.07	.13
calving difficulty	-.60	-.31	-.36	-.02
birth weight	.34	.37	-.07	.30
progeny preweaning gain	-1.02	-1.00	-1.25	-.26
mature weight	.07	.21	-.09	.25

The closest any of these traits comes to approximating muscling is measurement of fat trim. These results indicate that selection for reduced fat trim would result in delayed puberty, decreased fertility, increased birth weight and calving difficulty and increased preweaning

growth of progeny. These relationships are generally not very strong, but they have sufficient strength to indicate that single-minded selection for increased muscling in breeds used primarily as components of the commercial cow herd would diminish productivity in those cows.

What happens if we move to an extreme in muscling? As indicated previously, emphasis on extremes will frequently lead to some rather major problems affecting productivity. In fact, this is a major force that dictates changes in ideal type. There is no reason to believe that selection for extremes in muscling would be any different. In fact, this is a case where we already know what happens when we go too far. We understand quite a bit about the reproductive problems that will occur when a cow has too little fat. In addition, some breeds will almost certainly experience increased incidence of double muscling if selection emphasizes extremes in muscling.

The cow, as is true of females of other species, must maintain a reasonable amount of body fat or she will tend to become anestrus (Richards et al, 1986). Selection for muscling or leanness, without adequate attention to reproductive efficiency, will probably lead to a higher proportion of cows with insufficient body condition to maintain regular calving intervals. It may be that genetically reducing body fat will be accompanied by a reduction in the amount of fat a cow must maintain to be reproductively efficient. However, without incorporating reproductive performance into the selection criterion, the reduction in body fat resulting from selection for muscling will likely be more rapid than any changes in the ability of the cow to maintain reproductive status with reduced body fat.

Several breeds of cattle have, at low frequency, a gene leads to the condition referred to as "double muscling". This condition was recently reviewed in a thesis here at Oklahoma State University (Tinker, 1987). Double muscled cattle are noted for extremes in conformation and very lean carcasses. It is generally agreed that the condition is determined by genes at a single locus, but it is not a clear dominance-recessive relationship. Therefore, the heterozygote has some of the double-muscled characteristics. If selection favored heavily muscled individuals, it is probable that some heterozygotes would be selected and the frequency of the gene would increase in those breeds where the gene is present. This would lead to a fairly rapid change in muscling and rate of fat deposition. There are, however, some problems. Double-muscled cattle experience larger birth weights with increased incidence of calving difficulty. There is a tendency for double muscled cattle to be less adaptable to stress. Carcasses from double muscled cattle have been slightly more likely to be dark cutters, the low amount of fat cover makes the carcasses more likely to be dry and marbling is decreased. Cows that are double muscled tend to have smaller pelvic areas which compounds the calving difficulty problems caused by larger birth weights. Delayed puberty, reduced fertility and a decrease in milk production have also been reported.

If selection objectives include an advantage for heavily muscled cattle, care must be taken to avoid the problems associated with extremes in leanness and muscling. These problems will be particularly

damaging if they occur in breeds that are major contributors to the commercial cow herd. Reductions in reproductive efficiency in the cow herd would completely eliminate any advantages that might be obtained from leaner cattle going to slaughter.

Guidelines for a balanced program. Selection theory tells us that the most efficient route to improvement is to establish our selection objective and then derive the index of performance traits that has the largest correlation with that objective. This process assumes that we have a clear understanding of the economics of the objective and that the genetic parameters for the traits in the objective are estimated well. These assumptions are met only partially but enough is generally known to make some recommendations.

There are apparently some who believe that emphasis on large framed cattle has accomplished much of what it was originally designed to do (perhaps more). Current economics may justify more emphasis on muscling and leanness than has previously been the case. Does this justify single-minded selection based on muscling? The clear answer is no! The selection objective, even with an increased emphasis on muscling, should still include other traits that contribute to efficiency of production. This brief review indicates that some of those traits, particular those associated with reproduction in the female, would not be enhanced by single trait selection emphasizing muscling.

One approach might be to decide that muscling is important enough to establish it as our sole criterion for selection until some improvement is made. This approach would, apparently, lead to a decline in reproductive efficiency. We might ease our fears by telling ourselves that we will stop when we reach optimum muscling. The history of defining type in livestock tells us that we are not very skilled at knowing when to stop. The correlated decline in reproductive efficiency is also unnecessary. This approach is still single trait selection, even if we tell ourselves that we will change the program once we get where we are going.

More appropriately, a selection objective will be defined that includes muscling as a major component. A complete definition of the selection objective is beyond the scope of this paper. This definition is difficult to obtain because of the numerous characteristics that contribute to economic efficiency in the cattle business and the fact that there are numerous segments, each with its own economic objectives and those objectives are not always compatible. However, some suggestions can be made concerning the effect that increasing the emphasis on muscling should have on other components of the selection objective.

Undesirable genetic correlations with birth weight and reproductive characteristics suggest increased attention to these traits if selection emphasis is placed on muscling. Bulls that sire calves that cause calving difficulty should not be tolerated. Similarly, heifers that are unable to calve as two-year-olds and cows that do not calve at regular yearly intervals should be discriminated against. Bulls that

regularly sire heifers that become inefficient cows, should not be retained once such identification is made. Care taken in these areas should reduce the probability that problems caused by "going too far" will arise.

What about extremes? It is frequently said that there need to be some cattle that are too large to bring up the level of the cattle that are too small. The corresponding statement for muscling would be that there need to be some cattle that are too heavily muscled to bring up the level of the cattle which are light muscled. There would be absolute truth in these statements if these were the only important characteristics. The amount of truth in them is reduced proportional to the number of other characteristics that are important and the degree of any adverse relationships among the traits in question. There are, apparently, undesirable genetic correlations between muscling and several traits that are components of cow herd efficiency. These genetic correlations, along with the possibility of double muscling, should lead producers to be wary of individuals that are extremely heavy muscled.

An individual with extremely heavy muscling may be a major contributor to improvement if the other keys check out. Was it too large at birth? Does the dam calve easily at regular intervals? Do calves by the sire lead to increased calving difficulty? Is reproductive development normal in the individual and its sibs? Is growth performance appropriate? Is there evidence that the heavy muscling may be due to the gene for double muscling? This may be a truly outstanding individual if the correct answer is obtained for each of these questions. If not, this individual may contribute but should not be the center of any organized breeding programs.

Selection of extremes without regard to other traits is analogous to running down a hill while trying to navigate through a mountain range. It was an easy slide down but you must climb back up if the pass is at high elevation.

What about selection in different breeds? It was established earlier in this paper that our numerous breeds of beef cattle do not share the same characteristics. This fortunate situation leads to use of breed complementarity when crossbreeding systems are designed. Growth rate and carcass merit can be provided in the calf through the sire without having much of an effect on the maintenance requirements or reproductive efficiency of the commercial cow herd. Commercial cows can represent breeds with smaller size, higher fertility and adequate levels of milk production.

This diversity among breeds leads to the question: Should the selection objective be the same in all breeds? The answer is surely negative, although probably only in the sense that the relative importance of various traits should be different. Reproductive performance is still important in a breed that is used only as a terminal sire since someone must own the cow that produces that sire. Similarly, growth is an important consideration in breeds that are major

contributors to the commercial cow herd since an appropriate balance must be maintained between optimum size for efficiency of the herd and the fact that the cow still contributes half of the genes to the calf.

Some breeds can be identified as terminal sire breeds, while others excel in those traits associated with efficient cows. Despite such arbitrary classifications, it is probably in the best interest of each breed to emphasize a balance of traits while ensuring that nothing is done to damage their primary utility. Historically, those breeds of livestock that cannot serve broad segments of the commercial industry, have become novelties.

Summary. A change in the focus of selection in beef cattle leads to an array of questions concerning the effects on overall productivity. Muscling, as a selection criterion, would have some desirable effects on carcass merit and lean growth efficiency, but without a balanced selection program, would have adverse effects on cow herd efficiency. With muscling, perhaps more than with many other traits, avoiding extremes is critical because of possible adverse effects on cow fertility and the possibility of increasing the frequency of the gene that leads to double muscling. Cattle breeders must be certain that if steps are taken to identify individuals with superior muscling, attention is also paid to adequate fertility, growth, calving ease and maternal ability.

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