

THE EFFECT OF BODY SIZE ON PRODUCTION EFFICIENCY IN CATTLE

BREED COMPARISONS AND INTER-BREED RELATIONSHIPS

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SUMMARY

The effect of body size on the production efficiency of different breeds of cattle is considered only after examining the more general problem of breed comparisons in relation to genetics, nutrition and production physiology.

Genetic problems include what breeds and crosses to compare, how to set up a structured multi-breed population, and what breeding programme to follow with a view to practising across-breed selection. The main nutritional problem is what feeding system to adopt without prejudicing the outcome of a breed comparison, and mention is made of the advantages and disadvantages of *ad libitum* feeding with a complete standard diet. The main problem of production physiology is defining optimal performance.

Indirect assessment of optimal performance, if it is to be effective, should be based on inter-breed relationships among characteristics of economic importance. Several inter-breed relationships are discussed, and those involving mean mature body size are considered with reference to making breed comparisons for productive efficiency. Some examples are given of specific breed comparisons with the effect of body size included and excluded.

Breed comparisons in cattle are discussed under three headings: 1) genetic problems, 2) nutritional problems, and 3) those associated with the assessment of productive merit.

GENETIC OR BREEDING PROBLEMS

Whether we are improving cattle by between-breed selection or by what is now popularly called "breed substitution", or by crossbreeding either to introduce "new blood" into a breed which will continue to retain its name as a purebred or with the object of producing a new breed, or whether we are

crossing to compare the relative merits of different breeds of sire on the same dam breed, in all cases we end up with genetically different groups to be compared for productive merit.

At this point we might pass straight on to the problems of making specific breed comparisons. But this would be evading the main issue. The outstanding genetic problem of breed comparisons, recently reviewed by Dickerson (1969), is what breeds to compare, what crosses to make and what breeding programme to pursue thereafter. The problem arises because of the very large number of breeds that could potentially be compared.

There are at least 250 major breeds of cattle spread throughout the various countries of the world, and Mason (1969) in his dictionary of breeds lists more than twice as many minor breeds. So we have something approaching 1 000 different breeds of cattle to compare.

Testing all breeds might just about be possible under certain conditions, and later I will refer to the possibility of international testing.

If, however, we were to make all possible first crosses, the number would amount to almost one million. If we then think of making triple or multiple crosses or back crosses, the number of possibilities rapidly approaches infinity. Thus, on the one hand, testing all crosses is quite impossible, while on the other hand, without testing, the odds against hitting upon say, an outstanding triple cross by chance are many million to one, although we might persuade ourselves that good sense or reasoning and some available information might reduce these odds to a few hundred to one.

Not unnaturally, selection in practice goes for those few breeds reputed to have the best performance in terms of the criterion currently in fashion, as high growth rate appears to be at present, or high total milk yield.

However, prior to making any choice, one question we should ask is this: given facilities for testing N animals for production efficiency, how should numbers be distributed within and between breeds in order to maximise the probability of finding a breed or breeds with high performance. At one extreme we can have all animals on test from the same breed, while at the other extreme we would include as many breeds as animals, that is, one animal per breed. For a given genetic objective, we must determine at what point between these extremes the best solution lies. Surprisingly often, the answer will be to use relatively few animals per breed and a large number of breeds.

Before deciding what crosses to make or compare, it is important to consider another question—how the breeding programme is to be continued. If the full benefits of hybrid vigour are to be realised as an added rather than an alternative method of improvement, the narrow perspective of a closed random breeding structure may have to be largely abandoned. Geneticists warn against inbreeding within a breed as this leads to depression in performance. Similarly at the breed level, perhaps they should warn against a closed random breeding structure, however many crosses were originally involved in its construction.

Briefly then, let us suppose that it is desirable to test the optimum number of breeds for the facilities available, and that it is desirable to maintain heterozygosity to boost performance, and that it is also desirable to maintain maximum

genetic variation for selection to operate upon. Then in all three cases we reach the same conclusion that in general we should make use of a very large number of breeds—in practice usually the maximum number obtainable—with relatively few animals per breed. In addition we should operate a breeding system involving the continued crossing of breeds and of crossbreds—interbred in such a way as to maintain both heterozygosity and genetic variation.

In such a structured multi-breed population, selection of sires or individuals could be practised in the normal manner but with this one very important proviso (one which will be referred to again later)—that the selection criterion operates *uniformly* across all the breeds and crosses. Crudely translated, this means the selection criterion should be so arranged that the animals that would be chosen by mass selection would tend to be broadly the same as those that would be chosen by selection within breeds and crosses. Selection criteria with this property can be constructed provided we have suitable information on inter-breed relationships.

Breed comparisons and inter-breed relationships are still very much a research problem and there is a big distinction between selecting breeds for research and for commercial production. For example, it may not serve research interests at all well to pick the few breeds that are extreme for some characteristic. The most balanced and unbiased assessment of a population always comes from a random selection. Provisionally therefore, one might advocate the study of a random selection of breeds and crosses as the first step towards understanding breed differences. I will refer again later to this research approach in the section on inter-breed relationships.

NUTRITIONAL PROBLEMS

Breed comparisons or any comparison of genotypes for any character but especially for body composition and efficiency of food utilisation depend on the feeding system adopted. Breed differences are thus undefined unless the feeding system is fully specified.

The crux of the problem is that sufficient experiments cannot be done to determine breed differences in growth and development, lactation and food consumption separately in each of the very large number of different feeding systems possible. A way round this problem suggested by Taylor and Young (1966) was to look for a general form of equation interrelating growth rate, weight, food intake and age, with individual or breed differences in growth and efficiency represented by different parameter values. These parameters would, by definition, be independent of any particular growth and food intake curve. They would contain all the relevant information on each breed's intrinsic efficiency characteristics. All other measures of a breed's efficiency would depend on the weight, or gain, or food intake, and on the age and age intervals used, and could therefore be given different values according to the choice of the experimenter. The same approach could be applied to lactation performance.

We do not yet know any easy method of estimating these parameters in

individual animals because of the impossibility of making the same animal grow simultaneously at two different rates on two different levels of food intake. If, however, genetically similar groups can be put on different levels of food intake—as in the case of a breed or a sire progeny group—then it is possible to get estimates of parameters for efficiency of maintenance and efficiency of growth and possibly efficiency of milk yield. But such a procedure requires quite elaborate experiments to evaluate a breed's efficiency characteristics, and most people are naturally reluctant to undertake them.

In the absence of such a full-scale experiment, the problem of what feeding system to adopt to obtain valid comparisons remains. Since any attempt at controlled feeding may prejudice a breed comparison, the only alternative left is to let each genotype decide its own food intake, that is, use an *ad libitum* feeding system.

In practice, however, an *ad libitum* feeding system, together with recording of individual food intake, is very difficult to operate. For if concentrates, hay, silage, sugar-beet pulp, etc., are all fed *ad libitum* then, quite apart from the labour of recording individual intake of each foodstuff, different breeds will consume different proportions of the different foodstuffs, and there is the difficulty of combining the different foodstuffs into a single acceptable figure. There are very many ways of doing it, each leading to a slightly different result when comparing animals or breeds for efficiency.

COMPLETE STANDARD DIET

To overcome these difficulties of *ad libitum* feeding, A.B.R.O. has devoted a great deal of effort over the last five years or so to obtaining a complete standard diet for cattle. And A.B.R.O. is deeply indebted to British Oil and Cake Mills Ltd., as it then was, or U.K. Compound Feeds Ltd., as it now is, for the tremendous effort they put into developing such a pelleted diet. Details of this diet have been discussed by GIBSON (1969). It essentially contains 30 per cent of half-inch straw as the necessary length and level of roughage to allow normal rumination and normal milk composition.

The more obvious advantages of a standard complete pelleted diet are constant food composition for all animals, which, as we have seen, is especially relevant for *ad libitum* feeding; a reasonably constant basis of comparison from year to year and from season to season allowing the slow build up of comparable results over the years; and the problem of when to change from one ration to another so that different breeds are treated alike is bypassed. Results obtained by different institutes can be compared without any special difficulties over the interpretation of the nutritional units used.

Another potential use of a standard complete diet is that co-operative testing could be extended to animal breeding institutes in different countries, so that breeds could be tested and compared prior to importation. Co-operative testing on an international basis may sound a little far-fetched but it is quite a feasible proposition. Exporting the complete diet, instead of importing the cattle, could

considerably increase both the extent and effectiveness of breed comparisons, in addition to greatly lowering the cost.

The main limitation of any standard complete diet is inherent in its very nature. It is only one diet out of many. Nutritionists will sooner or later claim that some other combined ration is much better. Breeders will say that the results are not applicable to their methods of rearing. Those are very valid criticisms, but they only amount to saying that a standard complete diet won't give all the answers—and of course, it would be naive to imagine that it or anything else ever would.

The more practical limitations of the diet as used at present are that it does produce some cases of bloat in stalled animals, and some animals seem to go off food around calving. While, like many other things, it falls short of the ideal, it is nevertheless an extremely useful working tool for breeding experiments with cattle.

I might add that the two main experiments with cattle being set up by the Animal Breeding Research Organisation are naturally both wholly designed around this complete standard diet and that both experiments include breed comparisons as part of their design.

This section on nutritional problems in breed comparisons might be summed up as follows.

To determine optimal feeding systems for any breed would require very extensive trials based on a series of controlled feeding levels, several of which might have to be unproductive. Since at present we do not know the optimum, and since any controlled feeding system other than the optimum may seriously prejudice the outcome of a breed comparison, the only alternative at present would seem to be an *ad libitum* system.

In practice, to operate an *ad libitum* system satisfactorily, a standard pelleted diet is probably necessary. However, we must keep in mind that performance on an *ad libitum* system may not correspond to optimal performance, and that an *ad libitum* feeding system, on its own, can never provide us with the necessary information for determining what the optimal feeding system is.

PRODUCTION PHYSIOLOGY AND THE ASSESSMENT OF PRODUCTIVE MERIT

The third problem in breed comparisons is the assessment of productive merit. The relevance and accuracy of our assessment is closely related to and limited by the current state of knowledge on production physiology—the combination of reproductive physiology, the physiology of growth, meat physiology and lactation physiology—which shapes our decision on what characters should be observed, and how and when to measure them.

To begin with, let us consider the following restricted problem: we are presented with two specific breeds and are also given a *clearly specified basis for comparison*, and are then asked to compare them and determine whether or not one breed is superior to the other.

This is a straightforward problem, and the method of comparing breed means is well established. Reasonably accurate comparisons usually require that each breed is represented by a fairly large number of animals because of within-breed variability. If we know the magnitude of the difference we are looking for, and also have an estimate of the within-breed variation, then the number can be evaluated. To detect a difference of 2 to 3 per cent in body weight, about 50 animals per breed are required; whereas for 305-day milk yield about 400 animals per breed are required. Such numbers immediately show that few institutes have facilities for comparing more than two or three breeds with this degree of accuracy.

In practice, we tend to leave many of the questions unspecified until the experiment is over. We set up a breed comparison experiment, we observe various characteristics, body weights, growth rates, milk yields, or perhaps we slaughter the animals and do some carcass analyses. Then we start asking specific questions such as which breed has the higher growth rate between 6 months and 1 year of age; or which breed has the greatest milk yield for 305 day lactation excluding lactations less than 100 days; or the point at issue might be which breed has the highest dressing out percentage at a body weight of 450 kilograms. So long as the questions remain specific, then the breed comparison can be made without undue difficulty.

However, if the two breeds were slaughtered at the same body weight, somebody is sure to object to the conclusion that one breed has, for example, better muscle-bone ratio than the other; and often it is too late to go back to find an answer to the same question on a constant age basis or any other basis asked for.

The difficulty lies in the fact that the number of such questions is unlimited. Which breed turns out to be best will very frequently depend on the detailed condition laid down in the question. Comparisons are never absolute. They vary with nutrition, they vary with age, they vary depending on whether or not they are measured relative to body weight, and so on. It soon becomes apparent that the problem of "what to compare breeds for" is just as complicated and confused a problem as the previous problems of "what breeds to compare" and what feeding system to adopt.

Presumably, however, some criterion for comparison must be decided upon. It is only moderately helpful to say that most people would accept that breeds should be compared for optimal performance, but it is at least a start. Were the optimum performance points known or observable or calculable for each genotype, then the problem would revert to a simple comparison of means. Hence one approach to the problem of breed comparisons and breed selection is to attack the physiological and nutritional side of growth, development and lactation of genotypes and breeds with the specific objective of determining the optimal pattern of feeding, optimal ration composition, optimal age at slaughter and optimal lactation cycle. In addition, since an essential ingredient in achieving optimum performance is reliability in reproductive performance, an animal's optimal performance would have to be qualified by a probability of achieving it.

CURRENT RESEARCH ON OPTIMAL PERFORMANCE

The idea that beef breeds should all be compared at the same weight is no longer advocated quite so strongly as it was a few years ago. A recent publication by the U.K. Meat and Livestock Commission (M.L.C., 1970) entitled the "*High Cost of Overfatness*" advised producers to slaughter different breeds and crosses at different ages and weights, to obtain greater economic efficiency. JOANDET and CARTWRIGHT (1969) give tables of optimal ages and weights for slaughter based on maximum economic return for a number of different beef breed types comprising pure *Hereford* and 11 types of *Hereford-Brahman* crosses. Optimal ages ranged from 17 up to 22 months and optimal slaughter weights ranged from 334 up to 400 kg. Differences in profit of up to £10 per animal were estimated depending on whether a breed was slaughtered at 400 kg or its optimal weight. The authors conclude that "The magnitude of these differences show the importance of *adequately* comparing breeds and crosses and of comparing them at the point of maximal efficiency for each". FRANKE and CARTWRIGHT (1969), in a similar study, also found considerable breed differences in optimal slaughter weight. It would be most interesting and informative to see carcass traits and body composition of different breeds and crosses compared at optimal slaughter weight.

For milk production, most people would again agree that breeds should be compared on the basis of optimal performance. The optimal performance problem in the case of milk is that of determining the pattern of feeding for maximum efficiency, together with the lactation intervals for optimal lifetime performance. Some recent work by BROSTER (1969) shows that a higher rate of feeding according to yield in the early part of lactation leads to a higher overall performance, but research specifically aimed at determining optimal performance has a long way to go yet.

INDIRECT ASSESSMENT OF OPTIMAL PERFORMANCE

A partial solution to the problem of comparing breeds or genotypes for optimal performance is to use the technique of indirect assessment—the equivalent of indirect selection, to which the geneticist or animal breeder resorts when faced with the problem of not being able to measure what he really wants to measure. The technique is variously powerful, weak, or abused, because it is often very tempting to adopt a criterion for indirect selection without sufficient justification simply because it is relatively easy to measure and is inexpensive in terms of time and money.

The important question we should keep asking is whether selection for the observed measurement is really likely to improve optimal performance. The average expectation from disturbing the natural equilibrium is probably a deterioration in optimal performance—this because any selection criterion will usually be genetically correlated with a large number of homestatically interrelated

components of performance which are not usually observed but which perhaps should be. Most of the measurements at present used for indirect selection have not yet been adequately shown to be genetically correlated with optimal performance.

The present climate of opinion is that improved criteria for comparison or selection will depend on more direct measures of efficiency of production. For example, in a performance test of beef sires for efficiency of growth, measuring both growth rate and food consumption might be recommended but with either no carcass assessment or, if included, at a fixed weight or age. I am not necessarily opposed to this, but the question must be asked whether in such circumstances the additional measurement of food intake increases the genetic correlation between the observed character and optimal performance. Unless this fact is first established, there are no real grounds whatsoever for introducing the scheme or using the character for comparing breeds.

The accuracy of indirect assessment can be measured by the currently existing correlation between the observed measurement and optimal performance. Hence any other measured characteristic associated with the observed measurement but uncorrelated with optimal performance can be used to increase the accuracy of indirect assessment. This is part of the theory of selection indices. In other words, we should do what we can to avoid comparing genotypes or breeds for characteristics that are uncorrelated with optimal performance by excluding from our breed comparisons irrelevant characteristics that cloud the outcome. The question of what information is necessary to do this brings us to the subject of inter-breed relationships.

This section on the assessment of productive merit might be summed up as follows:

Specific breed comparisons present no problems provided the characters being compared are clearly specified. The major problem is "what to compare breeds for". The theoretical answer is to compare breeds for optimal performance. We either do not know how to do this, or when we do, the testing procedure is considered—and perhaps rightly so—to be too elaborate and costly to be put into operation.

In practice, the solution is to compare breeds by indirect assessment of optimal performance. It is then of prime importance to know the genetic correlation between the observed measurement or index and optimal performance, and equally important to recognise that its estimation must be based on inter-breed statistics.

INTER-BREED RELATIONSHIPS

Just as we need estimates of heritabilities and genetic correlations for determining effective methods of within-breed selection, so also for between-breed comparison and selection, we likewise need to know phenotypic and genetic relationships at the between-breed level among all the characteristics of economic importance and any others we may be interested in. The most balanced and effective method of obtaining inter-breed relationships applicable to the present

population of about 1 000 breeds of cattle or to some sub-population, is, as was mentioned earlier, to use a random sample of breeds.

Furthermore, just as there are formulae for finding the number of offspring per sire progeny group to give the best estimate of heritability, so a similar formula gives the number of animals required per breed to give the best estimate of an inter-breed regression. The number of animals per breed usually turns out to be quite small—from 2 to 10 animals per breed. Thus, even with fairly limited experimental facilities, an experiment involving 30 or more breeds could be carried out without undue difficulty. An experiment of this kind has recently been started by A.B.R.O., with the objective of estimating interbreed relationships involving food intake.

Much data from many different experiments on many different breeds has accumulated in the literature on characteristics such as growth rate, body weight, body composition, milk yield, milk composition, conception rate, and so on. Most of the results are not strictly comparable, having been carried out in many different countries and environments and with different feeding systems and types of ration. However, a great deal of useful information on inter-breed relationships can be extracted statistically. Thus analyses can be restricted to breed differences obtained within experiments. In addition, mean values quoted for the same breed from different experiments can be used to obtain estimates of between-breed components of variance and covariance.

The inter-breed relationship between mean birth weight and mean mature maternal weight was examined in this way using a sample of 167 breeds, and an inter-breed regression coefficient of 0.74 ± 0.05 was obtained for birth weight on maternal weight. The birth weight of a breed does not appear to increase in proportion to dam weight but more slowly; in other words, heavier breeds tend to have relatively lighter calves. In a breed comparison therefore, mean birth weight should perhaps be expressed as a proportion of mature metabolic weight, a result equivalent to that found by DONALD and RUSSELL (1970) for sheep breeds.

An analysis based on 158 d.f. between breeds and 283 d.f. for replicates within breeds, showed that butterfat percentage tended to decrease slightly as total milk yield increased, but not significantly.

A similar analysis of the inter-breed relationship between total milk yield and mature body weight presented many difficulties. The genetic inter-breed regression appeared to indicate that heavier breeds tended to have a proportionately greater total milk yield or possibly a yield slightly more than proportionally greater. The main difficulty was associated with the confusion introduced among measures of total yield by variable lactation lengths.

Another more general example of an inter-breed relationship is that between mature size and time taken to mature by different breeds or strains within a species (TAYLOR, 1968). The relationship so obtained can be used to eliminate the effect of size from specific breed or sex comparisons. Two scale changes are required. Size at all immature stages had to be scaled in accordance with mature size. The corresponding age conversion is effected by dividing age by the 0.27 th power of mature body weight to produce a metabolic age scale. When these

allowances are made for size differences, the growth and development of our domesticated species, breeds and sexes all tend to become approximately the same.

Inter-breed relationships involving food intake would be of considerable interest, but the necessary information is difficult to obtain. However, by examining the available evidence, some probable form of relationship can be obtained.

From the dependence of heat production on mature metabolic weight, it can reasonably be inferred that, in mature animals, genetic differences in food intake are proportional to genetic differences in mature metabolic weight. A suitable procedure for comparing the pattern of food intake of different breeds during their growing period would therefore be to scale food intake at immature stages by mature metabolic weight and convert age, as before, to a metabolic scale. The result of this procedure, as far as can be seen from available data, is to produce a transformed pattern of food intake during growth that tends to be approximately the same for different breeds.

If, when suitably adjusted for size, most breeds tend to show a quantitatively similar pattern of growth and development and also of food intake, then most breeds must also tend to exhibit a similar pattern for any combination of these. In other words, we can provisionally conclude that most breeds will tend to show approximately the same pattern of productive efficiency during growth. This general similarity must include similarity in optimal efficiency. It follows that there is unlikely to be any systematic association between the optimal efficiency of a breed and its mature size.

This claim that efficiency is independent of body size has been made on many occasions; both BRODY and KLEIBER made it in the 1930's. More recently, within-breed studies of production efficiency involving growth rate and/or milk production have, in general, come to the same conclusion (HOOVEN, MILLER, and PLOWMAN, 1968; KRESS, HAUSER and CHAPMAN, 1969; WILSON, GILLOOLY, RUGH, THOMSON and PURDY, 1969). Suppose we accept it and conjoin it with the argument previously referred to concerning the accuracy of indirect selection. It then follows that once the effect of size has been removed, and provided observations are taken at comparable stages of development, then most measures of efficiency of production will become more closely correlated with optimal performance. Hence we must exclude size from all our breed comparisons of production efficiency; and, by looking at what remains, we may get a clearer idea of differences in optimal efficiency.

A necessary comment at this stage may be that if the non-food cost per animal is proportional to the food cost per animal, then it can be ignored. If, however, part of the non-food cost per animal remains the same whatever the size of animal, then production efficiency when extended to include the total economic cost of production will obviously not remain independent of body size. I do not know what weighting factor should be given to this constant non-food component, and I do not intend to pursue here the economic arguments in favour of large size and the counter-arguments in terms of more expensive testing and slower rate of genetic improvement.

The remainder of this talk consists of looking at some examples of observed breed differences, before and after the effect of size has been eliminated.

THE EFFECT OF SIZE IN SOME SPECIFIC BREED COMPARISONS

Body weight and growth rate

In the British MLC Beef Recording Scheme, body weight at 400 days is the criterion on which bulls are at present ranked. KILKENNY (1970) gives mean body weights at 200 and 400 days obtained from this scheme for bulls of a number of beef breeds and these are reproduced in Table I as 400-day weight, growth rate in kilograms per day between 200 and 400 days, and also percentage growth rate over the same period. For 400-day weight, *Charolais* tops the list. The correlation between 400 day weight and gain from 200 to 400 days is very high (0.96), so that 400-day weight is a reasonably good inter-breed measure of absolute growth rate.

TABLE I

*Average performance of bulls
(MLC data, KILKENNY, 1970)*

TABLEAU I

*Performances moyennes des taureaux
(données MLC, KILKENNY, 1970)*

Breed	Liveweight at 400 days (kg)	Growth rate from 200 to 400 days	
		(kg/day)	(% /day)
<i>Charolais</i>	514	1.18	.304 (10th)
<i>South Devon</i>	511	1.24	.330 (6th)
<i>Devon</i>	497	1.24	.344 (3rd)
<i>Lincoln Red</i>	482	1.09	.299 (11th)
<i>Sussex</i>	470	1.18	.347 (2nd)
<i>Hereford</i>	451	1.10	.335 (5th)
<i>Welsh Black</i>	446	1.04	.313 (8th)
<i>A. Angus</i>	420	1.07	.353 (1st)
<i>B. Shorthorn</i>	410	1.01	.337 (4th)
<i>Galloway</i>	347	0.81	.314 (7th)
<i>Bltd. Galloway</i>	318	0.73	.305 (9th)
Mean	442 kg	1.06 kg/day	0.326 %/day
Coeff. of var.	14.5 %	14.8 %	5.9 %

The ranking of breeds for per cent growth rate is shown in the last column. The *Charolais* ranks near the bottom; the *Aberdeen Angus* ranks highest. The correlation between 400-day weight and per cent growth rate has the small

insignificant value of 0.21. A minor adjustment would have to be made to per cent growth rate to render it free from any association with breed size; but it is not clear precisely what this allowance should be since heavier breeds are slightly slower maturing but at the same time have a higher per cent growth rate because they are less mature.

For those interested in trends, ten years ago, the rank correlation between the relative frequency of demand for A.I. by bulls of these breeds (English MMB figures for 1958/1959) and absolute growth rate was virtually zero (0.12) but the correlation with percentage growth rate was high (0.61). Today, or rather for 1968/1969, there is virtually no correlation between frequency of demand and percentage growth rate. On the other hand, there is some correlation with growth rate in kilograms per day (0.34), and if *Friesians* were included this would probably be much higher. A demand for high percentage growth rate ten years ago has been replaced by the current demand for high absolute growth rate.

The main question to be asked, however, is how close a measure of optimal meat production is 400-day weight likely to be? Relative growth rate, being almost uncorrelated with breed size, is likely to give a better indirect assessment of efficiency of production than either absolute growth rate or 400-day weight, which are both very highly correlated with breed size. But percentage growth rate and 400-day weight are virtually uncorrelated so that 400-day weight is likely to be an extremely poor *inter-breed* measure of optimal performance. The differences between breeds for percentage growth rate are very much less than for 400-day weight, the coefficient of variation being only 5.1 per cent for percentage growth rate as compared with over 13.0 per cent for 400-day weight. Breed differences in optimal performance are therefore more likely to be of the order of 5 per cent than 13 per cent.

COMPARISON OF BEEF BREEDS FOR PROFITABILITY

Both birth weight and food intake show inter-breed proportionality to mature metabolic body weight, and hence to each other. If, therefore, the feeding of a dam is the main cost of producing a calf, the cost of a calf should be proportional to its birth weight. Suppose the proportionality relationship were, say, one pound sterling per kilogram of calf birth weight. A *Friesian* calf with a birth weight of 40 kilograms would then cost about £ 40, whereas a *Jersey* calf with a birth weight of 25 kilograms would then cost £ 25.

In Table 2, this calf price differential of £ 1 per kilogram birth weight may be compared with those required for equal profitability given by KILKENNY (1970) for a variety of beef breeds and crosses and based on a realistic assessment of the probable effects of differences in growth rate and finishing weights of different breeds and their relationship to feed costs. Calf price differentials proportional to birth weight may not be so far wrong as average values for a variety of methods of rearing.

The conclusion might therefore be drawn that when calf prices are proportional to birth weight, there are only small differences in profitability remaining among the beef breeds and crosses listed. This example is, of course,

TABLE 2

*Calf price differentials to Friesian bull calf to give the same level of profitability
(from KILKENNY, 1970)*

TABLEAU 2

*Écarts — rapportés au prix du veau mâle frison — des prix des veaux
issus de différents croisements nécessaires pour obtenir un profit analogue
(d'après KILKENNY, 1970)*

Calf type/all bull calves	Intensive cereal beef (£)	Semi-intensive grass/cereal beef £	Differential of £1 per kilogram
<i>Hereford</i> × <i>Friesian</i>	0	+ 3	— 2
<i>Charolais</i> × <i>Friesian</i>	0	+ 3	+ 2
Réd beef breed × <i>Friesian</i>	0	+ 3	— 1
<i>Charolais</i> × Channel Island	— 6	— 10	— 6
<i>Charolais</i> × <i>Ayrshire</i>	— 6	— 5	0
<i>Angus</i> × <i>Friesian</i>	— 7	— 6	— 5
<i>Hereford</i> × <i>Ayrshire</i>	— 7	— 6	— 5
<i>Ayrshire</i> - Best type	— 7	— 12	— 5
- Average	— 12	— 14	— 7

restricted to singleborn calves, and does not deal with the potentialities of calf production involving increased twinning or multiple egg transfer from large to small dams. But these more complex schemes apart, the general conclusion to be drawn from these examples is that whenever allowance is made for differences in body size, most breeds are very similar in performance and productive efficiency. We might conclude from this that breeds are also probably very similar in their optimal performance, with marginal superiority in a few cases, and that this margin may vary with conditions and type of rearing.

Breed differences in efficiency of meat production appear to be relatively smaller than those for body weight or growth rate, and the same is true for milk production. We might rightly fear that larger and larger and more closely controlled experiments would be required to detect them, and unless existing facilities were correspondingly enlarged, the number of breeds or crosses that could be compared would be correspondingly reduced. However, obtaining highly accurate breed comparisons for productive efficiency may not be a worth-while objective in cattle improvement. There are very many situations where the overall genetic information return per animal could be greatly increased by foregoing such unnecessarily high accuracy. For example, genetic progress from selection will often be greater in a population containing many breeds and crosses than in an equivalent sized population containing only one or two. Or as we saw earlier, the best estimate of an inter-breed relationship is obtained with only 2 or 3 sires per breed and no more than 2 or 3 offspring per sire. I feel that there is great scope and many unexplored possibilities at the other end of the scale from the large experiment dealing with only one breed, and I look

forward to the time when multi-breed experiments and herds are a commonplace with no-one very surprised to find 20 or more breeds represented and crosses galore.

Reçu pour publication en novembre 1970.

RÉSUMÉ

EFFET DE LA DIMENSION CORPORELLE SUR L'EFFICACITÉ DE LA PRODUCTION CHEZ LES BOVINS. COMPARAISONS DE RACES ET RELATIONS INTERRACIALES

L'effet de la dimension corporelle sur l'efficacité de la production de différentes races bovines ne peut être étudié qu'après examen de la question plus générale des aspects génétique, nutritionnel et physiologique des comparaisons de race.

L'aspect génétique concerne le choix des races et des croisements à comparer, la manière d'établir un ensemble structuré de plusieurs races et le programme de sélection à suivre en vue de réaliser les croisements entre races. Le principal problème nutritionnel est le choix d'un système d'alimentation qui nuise le moins possible aux comparaisons de race. Les avantages et inconvénients de l'alimentation *ad libitum* avec un aliment complet standard sont mentionnés. Le principal problème de physiologie de la production est de définir la performance optimum.

Pour estimer correctement la performance optimum, il faut étudier les relations interraciales entre les caractères d'importance économique. Plusieurs de ces relations sont discutées. Celles impliquant la dimension corporelle sont considérées du point de vue des comparaisons raciales pour l'efficacité de la production. Quelques exemples sont donnés de comparaisons spécifiques de races avec ou sans considération de la dimension corporelle.

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