INTRODUCTION

In Continental Europe beef production is based on purebred dual-purpose cattle whereas in the New World the main source of beef is from purebred beef herds, mainly of the traditional British breeds. In Britain there is an important inter-relationship between the dairy and beef industries which allows cross-breeding and the associated benefits of heterosis and complementarity to be exploited in providing beef cattle for breeding and for slaughter.

Bulls to be selected for use in beef production can be classified according to their specific breeding functions:

i. Sires for pure-breeding dual-purpose herds.
ii. Sires for purebred beef herds.
iii. Terminal sires for cross-breeding.

The observed or measured performance of different animals in various characters is a function of the heritability of the characters and the total environment in which the animals are reared. The heritability of the character under selection has a major determining influence on the choice of testing method. Several economic characters of beef cattle that contribute to both productive efficiency and desirability of product have moderately high heritabilities (PRESTON and WILLIS, 1970). Performance testing must therefore be the major selection method in breeding plans to improve growth rate or feed conversion.

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Beef performance testing was developed originally in the U.S.A. American tests are related to feedlot production using cattle from purebred beef herds. Recent recommendations from the Beef Improvement Federation (1970) are that the bulls should be within the range 180 to 305 days old at the start of the test; the test period should last at least 140 days and it should be preceded by a settling period of at least 21 days. Test gain is considered to be the most important selection character although yearling weight is gaining increasing use and is commonly used in practice. Many values are indexed as a percentage of the test mean in order to facilitate comparisons. High energy diets are used during the test, typical of those normally used in feedlot production.

A different approach has been adopted towards testing beef breeds in New Zealand, where the bulls spend the test period grazing in groups. In tests reported by Dalton (1972) the bulls had a mean age of 280 days at the start of the test and the test lasted 280 days. Proposals were reported to reduce the age at the start of test to 180 days, and to give more emphasis to weight for age comparisons at the end of test, as opposed to test gain.

Early tests in Britain (Lewis, 1966) were based on the North American pattern but it became apparent that test gain was considerably influenced by pre-test management. It was decided therefore to consider the whole test as an adjustment period and base the estimate of breeding value on the final weight for age, adjusted to 400 days. Weight for age is a summation of birth weight, gain to weaning (the start of the test) and test gain. Relatively little emphasis is placed on daily gain during the test period per se.

British tests are orientated towards evaluating terminal sires for cross-breding. Bulls for performance tests are drawn from herds participating in the Meat and Livestock Commission farm recording scheme. Qualifying standards of pre-test weight for age are set for each breed. The mean age at the start of test has been reduced recently from 210 days (+30) to 170 days (+20) and the duration of the test has been increased from 168 to 210 days in order that the test should terminate at approximately 400 days.

A complete diet in the form of cobs containing mineralised barley and dried grass is fed ad libitum to facilitate feed recording so that estimates can be made of feed conversion efficiency. This is presented for each individual as a percentage difference from the test mean. The feed conversion efficiency is measured over fixed liveweight ranges in the latter part of the test.

A programme in which Dairy Shorthorn bulls are tested in Britain from 90 to 400 days has been described by Lewis (1972).

In France (Kräusslich, 1973) performance tests last from 126 to 154 days. Bulls of the beef breeds commence tests at 200-250 days of age and bulls from dual-purpose breeds at 150 days of age. The final assessments are based on the bulls' test gains and weights at 400 days and 270 days, respectively. The bulls are fed complete diets (containing cereals and dried lucerne) and they are either tied or individually penned to enable feed recording to take place.

In Germany (Kräusslich, 1973) the detailed operation of performance tests varies slightly from region to region. Dual-purpose breeds are tested from 50 days and terminate at either 365 or 420 days. In some instances they are tested over
the liveweight range from 100 Kg to 350 Kg. Terminal sires from beef breeds are
tested from 120 days and they finish at either 365 or 420 days. The bulls are
either housed in groups or tied individually and feeding systems are based on
maize silage (or hay) and concentrates.

Swedish test start at 30 days of age for dual purpose breeds and 150 days
for beef breeds. They terminate at 365 days. Diets consist of hay (ad libitum)
and concentrates rationed on feeding scales related to the bulls' liveweights
(Lindhé & Persson, 1969). The breeding value of the bulls is assessed through an
index based on weaning weight and test gain.

Danish tests (Kräusslich, 1973) for dual-purpose breeds start at 45 days of age
and terminate at 365 days. Bulls of the beef breeds are tested between 200 and
400 days of age. The bulls are housed individually and they are fed concentrates
and hay. Growth rate and feed conversion efficiency are measured and ultrasonic
measurements of backfat and eye-muscle area are also taken.

THE TESTING PERIOD

i. Age at start of test

Considerable attention has been focussed on this topic. Firstly, there has been
a desire to reduce pre-test environmental influences for bulls that have been
single suckled. Secondly, the validity of the whole performance testing approach
has been questioned because of high correlations that have been shown to exist
between weights at different ages as cattle grow. European data for tests starting
at earlier ages than the conventional 200 days for suckled calves (Lindhé, Persson
and Christensen, 1969; Lewis, 1972) conflict with the Cuban data (Willis and
Preston, 1970). In the European data the correlations between 100 day and 300
day weights are high and similar to the correlations between 200 day and 400 day
weights (Table 1). High correlations between weights at various ages have also

| TABLE 1 |
| Phenotypic correlations among growth traits |

<table>
<thead>
<tr>
<th>Correlated traits</th>
<th>LEWIS (Unpublished)</th>
<th>LEWIS (1972)</th>
<th>ALLEN &amp; LEWIS (1970)</th>
<th>LINDHÉ et al. (1969)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 day wt/300 day wt</td>
<td>0.85</td>
<td>0.80</td>
<td>0.90</td>
<td>0.81</td>
</tr>
<tr>
<td>200 day wt/400 day wt</td>
<td>0.64</td>
<td>0.80</td>
<td></td>
<td>0.86</td>
</tr>
<tr>
<td>Test gain from 100 days/400 day wt</td>
<td>0.87</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test gain from 200 days/400 day wt</td>
<td>0.60</td>
<td>0.68 **</td>
<td>0.32</td>
<td>0.69</td>
</tr>
<tr>
<td>100 day wt/test gain to 400 days.</td>
<td>0.40 NS</td>
<td>0.32</td>
<td>0.56 **</td>
<td></td>
</tr>
<tr>
<td>100 day wt/test gain to 400 days.</td>
<td></td>
<td></td>
<td>0.23</td>
<td>0.17 NS</td>
</tr>
<tr>
<td>Mean test gain from 200 days (Kg./day)</td>
<td>1.38</td>
<td>1.34</td>
<td>1.13</td>
<td>1.12</td>
</tr>
</tbody>
</table>

Gain to 300 days. P < 0.001 unless stated. ** = P < 0.01 * = P < 0.05.
been reported by Lindström & Maljala (1970) from Finnish tests conducted over the age range 60 to 365 days. However, Willis and Preston (1970) reported much lower correlations: between weight at 90 days and age at 400 Kg of \( r = +0.53 \) and between age at 200 and 400 Kg of \( r = +0.72 \). High energy diets were fed which produced a mean liveweight gain of 1.1 Kg/day. Reasonably high correlations between weights at various ages are to be expected in view of the part-whole relationships involved.

More recent data from British performance tests (Lewis, unpublished data) starting at approximately 200 days show a lower correlation \( (r = +0.64) \) between 200 and 400 day weights than those reported previously. This observation may be explained by *ad libitum* feeding of high energy diets which cause test gain to make a greater contribution to the final weight for age. This is reflected in an increased correlation between test gain and 400 day weight.

Theoretically, the performance test should start at the earliest opportunity after birth in order to minimise environmental influences. Even in this idealistic situation performance will be influenced by maternal factors such as the age and parity of the dam, her nutritional status and their effect on parturition and birth weight.

Bulls from dual-purpose breeds, where the dam’s milk is required for human use can be consigned to performance tests at any time after the uptake of colostrum. In practice this takes place between seven and 150 days of age. In single suckling situations it is unlikely to be practically feasible to commence tests before 150 days of age. Lindhé et al. (1969) proposed that beef bulls should be tested from 100 days of age but for practical management reasons tests in Sweden now start at 150 days and terminate at 365 days. (Lindhé, 1972.) This is also the lower age at which tests for beef bulls now start in Britain. Tests in Cuba with beef breeds were conducted from 90 days, terminating at 400 Kg. (Willis and Preston, 1970.) The conditions were quite different from those in temperate zones, facilitating relatively early weaning.

**ii. Age ranges within tests**

In group testing Allen and Lewis (1970) found that the younger bulls within tests starting at a mean age of 238 days showed above average liveweight gains. There was no simple explanation for this observation. However, in consequence it was suggested that age ranges within contemporary groups should be minimised.

**iii. Length of test/termination point**

The duration of the test will be influenced by the inter-relationship of three factors; the age at the start, the plane of nutrition and the age at termination. The test period should be sufficiently long for pre-test influences to be largely overcome. This is influenced by the plane of nutrition in the test which determines the scope for compensatory growth. The generation interval is minimised if the tests terminate when the bulls reach sexual maturity. The majority of performance tests are completed at 365 to 400 days. Unnecessarily long test periods add excessively to the direct cost of the testing programme and also have indirect influences by restricting throughout.
Two experimental tests have been conducted in Britain in which the bulls were retained to 500 days. There were very high correlations between the weights at 400 and 500 days of age: \( r = +0.96 \) (B. R. A., 1968) and \( r = +0.92 \) (Lewis, unpublished data). The rankings of the bulls at the two ages in the latter study was also highly correlated (\( r = +0.94 \)). The practical consequences of these relationships are illustrated by an example from the second test by the differences between the top three bulls selected at the two ages. Only one bull occurred in both selections but the mean 500 day weights of the bulls actually selected at 400 and 500 days of age differed by only 12 Kg. It is unlikely that this would represent more than a 3 Kg difference in the 500 day weights of the progeny of the bulls. It was concluded therefore that testing beyond 400 days was not justified.

The EAAP Sub-Commission Report on Testing Procedures (Kräusslich, 1973) recommends that the selection of bulls from performance tests should be made on the basis of the superiority for those characters required in the progeny. It was not recommended to end tests at earlier ages and/or lower weights than occur in commercial practice if there was much variability in the gains during the latter stages of the test due to accelerating rates of fat deposition. In these circumstances it was considered preferable to test to the optimum slaughter weight, even at the expense of generation interval.

**Feeding systems**

i. **General considerations**

The choice of feeding system will depend on the selection criteria, the management practice and whether or not feed conversion efficiency is to be recorded. If concentrates and roughage are offered separately, selectivity among dietary components can lead to the consumption of substantially different diets by individual bulls. This complicates comparisons of gain and invalidates estimates of feed conversion efficiency. The feeds should therefore be fed in a physical form which prevents the selection of individual ingredients, i.e. as complete diets with all the dietary components in a single pellet. The diets should be designed to enable the bulls to have *ad libitum* access in order that their performance should not be influenced by human factors.

There are strong phenotypic correlations between growth rate and feed conversion efficiency and indications that the genetic correlation is also high (Fitzhugh and Cartwright, 1971; Neiman Sorensen & Bech-Andersen, 1973). The measurement of feed conversion efficiency greatly increases the costs of performance testing and therefore its inclusion as a selection criterion demands careful consideration. If feed conversion efficiency is to be measured, it should take place over specific liveweight ranges during the latter part of the test:

- a) to avoid compensatory effects,
- b) to standardise maintenance requirements,
- c) to confine the assessment to a period when the animals are likely to be depositing most fat.
ii. Plane of nutrition

High growth rates, and therefore relatively high planes of nutrition, are important in performance tests for several reasons:

a) to minimise the generation interval and maximise turnover through the test centre,
b) to enable bulls to express their potential for growth,
c) to facilitate compensatory growth,
d) to compete with bulls reared on breeders' farms.

On the assumption that the chosen plane of nutrition will be at the top level of commercial practice, there will be problems if certain environments have different effects on specific genotypes. The literature on this subject has been reviewed by Preston & Willis (1970). The effects on cattle are less definite than with other species and this is possibly explained by the versatility of ruminant. In temperate regions the majority of beef produced will be within similar production systems. However, the situation could be different in tropical regions where several very different production systems might operate. In Britain sire breeds have been shown to rank very consistently under a wide range of environmental situations. (MLC, 1971.) Nevertheless, exceptional conditions should be avoided; for example, the selection of sires under temperate conditions and their subsequent use in tropical areas. Preston & Willis (1970) claim to have obtained excellent results from the selection of cattle on high nutritional planes when their progeny were reared on a variety of different feeding regimes in Cuba. They concluded that there was still a need for much work in this field and the possibility of important interactions in beef cattle could not be rejected. However, they stated that it was difficult to justify the practical value of incorporating such features into a sire selection programme.

Selection

i. Criteria

Growth rate and feed conversion efficiency are the main heritable factors which influence the economics of beef production. Linear improvements in profitability of commercial beef systems can be related to unit increases in daily gain (MLC, 1973). Other characters must take less precedence and should perhaps be included in selection programmes at threshold values or as part of a selection index. Their inclusion as major criteria will limit overall progress.

a) Carcase traits.—In the traditional British breeds the percentage of fat in the carcase is the most important variable constituent at a given weight or age and it largely determines the yield of saleable meat (Harrington, 1973). The developing use of ultrasonics allows measurements to be taken on live animals for the assessment of sub-cutaneous fat thickness and eye-muscle area.

b) Dystokia.—One of the consequences of selecting for growth rate is an increase in birth weight and an associated increase in difficult calvings. These
factors, and the inter-relationships with gestation length should be monitored in breeding programmes.

c) **Conformation.**—Conformation assessments should be restricted to factors such as skeletal soundness until there is a greater understanding of conformation in relation to carcase merit.

d) **Semen.**—Semen characteristics are not considered to be objectives for inclusion selection programmes but they have a threshold influence at the time of selection for other traits. Greater clarification is required of the relationship between fertility and semen morphological characteristics.

ii. **Presentation of results**

Growth rate, measured either as test gain or yearling weight are taken as the main criterion in most countries. In most cases bulls are compared on the basis of their relative performance i.e. the difference to the test mean. Daily liveweight gains over different periods and weights at various intermediate ages are presented as supplementary information. Other criteria, for example feed conversion efficiency, ultrasonic measurements and conformation scores are usually presented separately. In the U.S.A. values for performance characteristics are indexed as a percentage of the test mean in order to facilitate comparisons.

A rather different approach has been adopted in Sweden and selection indices are used. Originally the index related the merit of the bull (as a percentage) to the mean of the contemporaries, taking into consideration the heritability of the character (Lindhé et al., 1969). Since then (Lindhé, 1972) a more complex index has been introduced which gives a relative weighting of 40 per cent to each standard deviation of weaning weight and 60 per cent to each standard deviation of daily gain on test.

Indices are a means of combining together several characters to maximise progress but they rely on assumptions of economic values and heritabilities. Progress in the selection for more than one character is reduced by a factor of \(1/\sqrt{n}\), where \(n\) is the number of characters selected for, except where the characters are correlated. The comparison of weight for age is a much simpler index that can be grasped more readily by breeders and can be related to within herd recording. Many beef testing schemes have not yet reached a stage where sophisticated criteria are relevant. At their present stage it is much more important that there should be some simple, straightforward basis for selection.

iii. **The practical application of performance testing**

Performance tests can only assess characters exhibited in young growing cattle and as such their use in providing estimates of breeding value will have inevitable limitations. Furthermore, the practical success of a performance testing programme depends on the supply of cattle for the programme and the subsequent selection and use of the superior bulls.

William (1971) has suggested that most progress can be made in purebreeding situations when selection is based on performance testing followed by progeny testing. The inter-relationships of performance and progeny testing have been discussed by Steane (1974), particularly in relation to national cost-benefit returns.
in A.I. breeding programmes for which many of the resulting progeny are slaughtered. Performance testing is shown to return a yield even at relatively low selection intensities (performance 1 in 5; progeny 1 in 2). Sequential selection, i.e. the use of performance tested bulls until the progeny test results are available has an almost similar cost benefit except at high selection intensities (performance 1 in 20; progeny 1 in 8).

SUMMARY

In Continental Europa beef production is based on purebred dual-purpose cattle whereas in the New World the main source of beef is from purebred beef herds, mainly of the traditional British breeds. Bulls to be selected for use in beef production can be classified according to their specific breeding functions: 1. Sires for pure-breeding dual-purpose herds; 2. Sires for purebred beef herds; 3. Terminal sires for cross-breeding. Performance testing must be the major selection method in breeding plans to improve growth rate or feed conversion.

REFERENCES
