Duration of performance tests for growth rate, feed intake and feed efficiency in four biological types of beef cattle

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Abstract

Data from the centralised performance tests for young beef bulls in South Africa were used to determine the minimum test duration required to obtain an accurate measure of feed intake, growth rate and two measures of feed efficiency: feed conversion ratio and residual feed intake. Five breeds from four different biological types were used to investigate whether different duration tests are required for different types of cattle. The results indicated that a test of between 42 and 56 days is sufficient for measurement of growth rate when a linear regression equation is used to model weight vs. time. Feed intake required approximately 56–70 days to measure accurately, while feed conversion ratio and residual feed intake both required around 70–84 days. There was little evidence of consistent breed differences in the time required to measure the traits, and it was concluded that the duration of performance tests could be shortened from 112 days to between 70 and 84 days for all breeds with no loss in accuracy of the test. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Feed intake; Feed efficiency; Growth rate; Performance test; Beef cattle; Test duration

1. Introduction

Providing feed to animals is a major expense in most beef production enterprises, and so information on feed consumed and growth performance of cattle is useful for research and in cattle breeding schemes. However, measurement of feed intake and feed efficiency of cattle is expensive, and so any reduction in the cost of measuring these traits would be beneficial. An obvious way to reduce cost of measurement is to shorten the duration of the test period over which the traits are measured. While there are numerous reports on test duration required to measure growth rate (e.g. Swiger and Hazel, 1961; Franklin et al. 1987; Brown et al. 1991; Liu and Makarechian, 1993a,b; Archer et al. 1997), there is very little information available in the literature on the minimum test duration required to provide an accurate measure of feed intake and feed efficiency. Archer et al. (1997) recommended a test duration of 35 days for feed intake and 70 days for feed efficiency based on data collected on British breed cattle, but there are no studies to confirm this finding in independent data sets. Moreover, it is possible that...
the appropriate test duration may differ for cattle of different biological types. Studies in Australia have shown marked differences in feeding patterns between *Bos taurus* and *Bos indicus* cattle in the same feedlot environment (Robinson et al. 1997), suggesting that differences between breeds in time required to obtain a reliable estimate of feed intake may exist. The purpose of the present study was to investigate the test duration required to obtain an accurate measure of feed intake, growth rate and feed efficiency in cattle representing different biological types.

2. Materials and methods

2.1. Data

Data from the centralised performance test for young bulls (Phase C1) of the South African National Beef Cattle Performance Testing Scheme were used in this study. Five breeds with comparatively large numbers of records available were chosen to represent four major biological types used in beef production. The breeds used were Angus and Hereford (representing British breeds), Simmental (representing European-type breeds), Afrikaner [an indigenous breed of Sanga (*Bos taurus africanus*) origin] and Bonsmara (a stabilised composite comprised of 5/8ths Afrikaner and 3/8ths Hereford and Shorthorn). The data was collected at six government-owned central test-stations (ARC-owned since 1995) at Irene, Omatjene (in Namibia), Queenstown, Vryburg, Cedara and Glen from 1977 to 1997. Numbers of records available for Afrikaner, Angus, Bonsmara, Hereford and Simmental at each test station are given in Table 1.

The Phase C performance tests are conducted by sending bulls to central performance test stations where feed intake and growth data are collected for a period of 112 days (140 days prior to 1991), following a 28 day pre-test adjustment period (35 days prior to 1991). Up to 12 (8 prior to 1991) intakes of animals were tested per station per year. Entry criteria are imposed on bulls in an effort to minimise differences in age and weight of bulls entering the test. The diet of the bulls during the test period consisted of a pelleted ration containing 13.0 MJ ME/kg dry matter and 13% protein. The ration was composed of maize (400 kg/tonne), cottonseed (75 kg/tonne), wheat pollard (120 kg/tonne), lucerne (50 kg/tonne), maize rests (straw) (206 kg/tonne), molasses (90 kg/tonne), hominy chop (34 kg/tonne), urea (5.5 kg/tonne), salt (5.0 kg/tonne), limestone ground (14.2 kg/tonne), monocalcium phosphate (3.2 kg/tonne) and a vitamin–mineral premix which included the rumen modifier Rumensin (2.1 kg/tonne). Cattle were placed in pens with electronic gates which allowed individual access to particular feeders, and feed intake was recorded weekly during the test period, with the exception of the test station at Irene where feed intake was recorded fortnightly, but was divided by two to provide weekly records. During the test, animals were weighed every week after a 12-h overnight fast during which animals were not given access to food or water.

### Table 1

Distribution of bulls by test centre, and number of bulls with missing sire information

<table>
<thead>
<tr>
<th>Test centre</th>
<th>Afrikaner</th>
<th>Angus</th>
<th>Bonsmara</th>
<th>Hereford</th>
<th>Simmental</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irene</td>
<td>384</td>
<td>118</td>
<td>2188</td>
<td>70</td>
<td>986</td>
</tr>
<tr>
<td>Omatjene</td>
<td>38</td>
<td>0</td>
<td>6</td>
<td>0</td>
<td>41</td>
</tr>
<tr>
<td>Queenstown</td>
<td>0</td>
<td>587</td>
<td>768</td>
<td>385</td>
<td>260</td>
</tr>
<tr>
<td>Vryburg</td>
<td>55</td>
<td>96</td>
<td>2319</td>
<td>432</td>
<td>1299</td>
</tr>
<tr>
<td>Cedara</td>
<td>48</td>
<td>162</td>
<td>293</td>
<td>203</td>
<td>576</td>
</tr>
<tr>
<td>Glen</td>
<td>207</td>
<td>87</td>
<td>1214</td>
<td>36</td>
<td>240</td>
</tr>
<tr>
<td>Total no. bulls tested</td>
<td>732</td>
<td>1050</td>
<td>6788</td>
<td>1215</td>
<td>3402</td>
</tr>
<tr>
<td>No. bulls missing sire information</td>
<td>3</td>
<td>0</td>
<td>563</td>
<td>90</td>
<td>73</td>
</tr>
</tbody>
</table>
2.2. Analyses

Test durations ranging from 1 to 16 weeks were considered, with all tests beginning at the test start date, following a 28-day pre-test adjustment period. The length of test was progressively increased in weekly increments by including an extra week of feed intake and weight data in the data set analysed.

Growth of each individual was modelled by linear regression of weight against time on test, using the regression procedure of SAS (1989), and the regression coefficient estimates were used to calculate average daily gain (ADG) during the test, and the mid-weight (mean of start and end weights). The linear model fitted to weight data from each separate animal included an intercept, a linear term for number of days on test and the residual error term.

Information on daily feed intake (DFI) and growth was used to calculate two indices of efficiency. Firstly feed conversion ratio (FCR) was calculated as total feed intake divided by total gain. The second index of efficiency used was residual feed intake (RFI). Residual feed intake was calculated by modelling daily feed intake within each breed using the general linear model procedure of SAS (1989), with terms fitted in the model including a class variable for each test (defined as a unique combination of test centre, year and test number), and mid-weight raised to the power of 0.73 and linear average daily gain fitted as covariates. Residual feed intake was equated to the residual errors from the model. Relatively small numbers of animals in each test meant that it was not possible to fit separate regression slopes for each test, but results from Australian data [J.A. Archer, P.F. Arthur, R.M. Herd and E.C. Richardson, unpublished data] suggest that where conditions are relatively uniform across different tests, common regression coefficients across tests with a fixed effect to adjust for test effects are adequate.

Variance components for each trait and test duration were calculated from univariate analyses using ASREML (Gilmour et al., 1998). The model fitted included age and weight at start of test as covariates, test (unique test centre, year and test number combination) as a fixed effect, and sire fitted as a random effect. A number of records had missing sire information (see Table 1 for numbers missing in each breed). These records were retained in the data, as they provided information about the test group effect, but did not contribute to the sire variance component. Dam information was not used in the analyses as there was a limited number of dams with more than one progeny in the data, and the objective was not to estimate genetic parameters.

3. Results

A summary of the performance of the five breeds over the 112 day test is given in Table 2. In general

<table>
<thead>
<tr>
<th>Trait</th>
<th>Afrikaner</th>
<th>Angus</th>
<th>Bonsmara</th>
<th>Hereford</th>
<th>Simmental</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start age</td>
<td>Mean±S.D.</td>
<td>264±23</td>
<td>239±26</td>
<td>259±24</td>
<td>254±28</td>
</tr>
<tr>
<td>Start weight</td>
<td>Mean±S.D.</td>
<td>231±22</td>
<td>263±25</td>
<td>275±26</td>
<td>264±27</td>
</tr>
<tr>
<td>ADG</td>
<td>Mean±S.D.</td>
<td>1.23±0.17</td>
<td>1.70±0.26</td>
<td>1.61±0.24</td>
<td>1.57±0.25</td>
</tr>
<tr>
<td>(kg day⁻¹) Range</td>
<td></td>
<td>0.65–1.89</td>
<td>1.08–2.63</td>
<td>0.67–2.68</td>
<td>0.75–2.53</td>
</tr>
<tr>
<td>DFI</td>
<td>Mean±S.D.</td>
<td>8.94±1.08</td>
<td>11.11±1.25</td>
<td>10.52±1.31</td>
<td>10.10±1.24</td>
</tr>
<tr>
<td>(kg day⁻¹) Range</td>
<td></td>
<td>5.38–12.23</td>
<td>7.87–15.43</td>
<td>5.88–15.06</td>
<td>6.38–13.91</td>
</tr>
<tr>
<td>FCR</td>
<td>Mean±S.D.</td>
<td>7.28±0.90</td>
<td>6.60±0.73</td>
<td>6.62±0.78</td>
<td>6.52±0.76</td>
</tr>
<tr>
<td>(kg kg⁻¹) Range</td>
<td></td>
<td>5.43–12.48</td>
<td>4.65–9.56</td>
<td>4.15–10.91</td>
<td>4.44–11.34</td>
</tr>
<tr>
<td>RFI</td>
<td>Mean±S.D.</td>
<td>0.00±0.50</td>
<td>0.00±0.50</td>
<td>0.00±0.67</td>
<td>0.00±0.59</td>
</tr>
<tr>
<td>(kg day⁻¹) Range</td>
<td></td>
<td>–1.49–2.76</td>
<td>–2.47–1.83</td>
<td>–3.76–3.72</td>
<td>–2.35–2.28</td>
</tr>
</tbody>
</table>
the performance and amount of variation in Angus, Bonsmara, Hereford and Simmental were similar for most traits, while the performance of Afrikaner tended to be lower than the other breeds. The breed means for residual feed intake cannot be compared, as the within breed regression meant that all means were zero, and rankings of animals are only relative to other animals in the same population.

The magnitude of variance components for the five breeds considered is shown for ADG, DFI, FCR and RFI in Figs. 1–4, respectively. The variance components are not intended to be used as genetic parameter estimates, as any pre-test environmental effects which may not have been removed by the test entry criteria are partially confounded with sire effects. In addition, the bulls tested represent a selected sub-set of the South African cattle population for each breed, and this selection has not been accounted for in the variance estimates. De Rose et al. (1988) showed that pre-test environment and selection effects can be important when using post-weaning performance test data for genetic evaluation. However, the sire variance component estimated here represents real biological variation in the traits (caused by genetic and possibly some pre-test environmental effects) which has been separated from the residual variation which in turn includes measurement error among other things. Therefore the response in the variance components to increasing test duration is appropriate for assessing the duration required to minimise measurement error.

The residual variance for ADG decreased up to 42 days for Afrikaner, Angus, Bonsmara and Hereford, with no marked reduction occurring after this point. The residual variance appeared to take slightly longer to stabilise for Simmental, where approximately 56 days were required. Sire variance components had already stabilised by the time the

Fig. 1. Response in variance components of ADG to increasing test duration.
residual variance stabilised, and were of a similar magnitude to the estimate obtained for a 112-day test.

For DFI, the response in residual variance components to increasing test length was not as marked as for growth rate. The residual variance appeared to stabilise after approximately 56 days on test for Afrikaner, Angus, Bonsmara and Hereford, and after 70 days for Simmental. However, as the response curves were fairly flat, it could be argued that shortening the test further from these durations (e.g. to 42 days) would result in only marginal losses in accuracy, and the savings by using a shorter test duration might be justified. The sire variance components for DFI were stable after around 21 days on test.

Variance components for FCR measured using shorter tests behaved poorly, although they appeared to stabilise for longer tests (Fig. 3.). The reason for the non-sensical estimates obtained was considered to be a result of the poor distributional properties of FCR when the denominator (total gain) is close to zero or negative for some animals. This situation is likely to occur when short tests are used, as the daily variation in weight is large compared to the weight gain over a short period. Similar anomalies for FCR measured using short test durations were observed by Archer et al. (1997). The results for FCR suggest that residual variances stabilised after approximately 70 days in Afrikaner, Angus and Simmental (although there was a perturbation at 77 days for Afrikaner), and 84 days in Bonsmara and Hereford.

Residual variances for RFI stabilised after approximately 70 days for Afrikaner, Angus and Bonsmara, and after 84 days for Simmental and Hereford. However, as with DFI the response curve for RFI was relatively flat, and so shortening the test duration to as little as 49 days would result in only minor
losses in accuracy for all breeds. Sire variance components stabilised after 49 days for most breeds, with the exception of Afrikaner which took 56 days.

4. Discussion

There have been several criteria for assessing optimum test duration used in various reports in the literature. Many papers (e.g. McPeake and Buchanan, 1986; Franklin et al. 1987; Brown et al. 1991) have used phenotypic correlations between shorter tests and some maximum test duration, and assessed optimum test duration to be at a point where the correlation is greater than an acceptable threshold. This approach suffers from problems with autocorrelation, as the correlation between two tests of similar length (and therefore comprise largely of the same data) is high by definition, and fails to consider that the measured trait is composed of real biological variation and other variation, including measurement error. Heritability of the measured trait from different test lengths has been used as a criterion in other studies (e.g. Liu and Makarechian, 1993b). This approach recognises that the variance of the test outcome reflects both real biological differences between animals (in this case due to additive genetic variation), and unexplained residual error, and maximising heritability for minimum measurement cost is of interest in the context of using results in selection programs.

Archer et al. (1997) extended the approach of Liu and Makarechian (1993b) by calculating phenotypic and genetic correlations between shorter tests and the maximum test duration in addition to heritability, and assessed the optimum test duration as that which provides the maximum correlated selection response in the trait measured using maximum test duration. However, close examination of the results of Archer et al. shows that the genetic correlation between
shortened tests and the maximum test was high even for very short tests, and so the criterion used essentially reflected the test duration at which the residual error variance component was minimised. This result agrees with the expectation that the same trait is being measured in tests of different duration, but with less error in longer tests. Such reasoning would also suggest that the variance of the underlying biological trait of interest is likely to remain relatively constant with increasing test duration (assuming that the trait mean is independent of test duration). This was observed by Archer et al. (1997). Therefore the observed phenotypic variance (the sum of the variance of the underlying biological trait and the residual error) is probably sufficient to make a reasonable judgement as to the test duration required to minimise residual error variance without estimating variance components. This is likely to be useful where insufficient data is available to estimate variance components for traits of interest.

In this study a linear regression of weight against time was used to minimise the influence of random error in individual weight data. A quadratic regression was also tried, but the ADG calculated from the quadratic regression was very highly correlated with that from the linear regression and so results have not been presented. With a relatively short test it would be expected that growth during the test would be linear, and so for shorter tests a quadratic regression is unlikely to add useful information. Also, as there are normally fewer weights collected during a shorter test (unless frequency of weighing is increased), use of higher-order regressions may over-parameterise the model, meaning that ADG can be heavily influenced by individual weights which may deviate from the general trend.

Recommended test duration for measurement of growth rate in the literature include 112 days (McPeake and Buchanan, 1986; Franklin et al. 1987; Kemp, 1990, Brown et al. 1991), 84 days (Swiger and Hazel, 1961; Liu and Makarechian, 1993a,b) and 70 days (Archer et al. 1997). The studies recommending 112 days generally based their conclusions on the basis of phenotypic correlations with a 140 day test, and do not consider problems with autocorrelation of data, while those recommending shor-
ter tests (84 or 70 days) were based on variance components. The 42 days required to accurately measure ADG in this study is considerably shorter than even the recommendation of Archer et al. (1997). This was probably because animals in this study were fasted for 12 h before weighing, while those in the study of Archer et al. were weighed straight off feed to avoid any disruption to feeding patterns, and so would have had greater variation in weights due to gut-fill.

There are no studies with which to compare test duration for measurement of feed intake and efficiency other than that of Archer et al. (1997). The test duration required for accurate measurement of feed intake in this study (from 56 to 70 days) is longer than that recommended by Archer et al. (35 days), but is considerably shorter than the 112-day test this study was based on. The difference between the study of Archer et al. (1997) and the present study in time required to measure feed intake might be due to the impact of the weekly disruption to feeding imposed by the 12 h fast prior to weighing the bulls, as bulls were excluded from feed for 7% of the time under this protocol. Thus while the fasting regime decreased the time to measure weight gain (the limiting factor for measuring feed efficiency in the study of Archer et al. (1997)), it might have increased the time required to measure feed intake. An alternative explanation of the difference between the two studies might be found in differences in the accuracy with which feed intake was measured. In the study of Archer et al. (1997), feed intake was recorded using a fully automated system with meal residues weighed at the conclusion of each meal, while in this study feed intake was generally recorded in situations where animals had access to individual feeding positions, with meal residuals weighed manually on a weekly basis. However the relative accuracy of the two feed intake recording systems is difficult to assess.

The test duration required for measurement of FCR and RFI in this study (70–84 days) was similar to that found by Archer et al. (70 days). Both studies were reasonably conservative in their interpretation and even shorter duration tests might be used with little loss in accuracy. However, the results show that even with a conservative interpretation, the duration of test for measurement of the four traits considered could be reduced from 112 days to around 70–84 days without any loss of accuracy.

Differences between breeds in the response of variance components to increasing test duration were minor. There may have been a slight tendency for Simmental to require a longer test than the other breeds for some traits, but the differences were not consistent across all traits, and might be attributed to random variation. Thus there is little evidence to support the need for different duration tests for different breeds or biological types, despite previous observations of differences in feeding patterns and growth rates across breeds.

Variance components can be used, as in this study, to assess the test duration which provides the most biologically accurate measure of a trait on an individual. However, this approach fails to account for the cost of each extra week of measurement. It is possible that the economically optimum test duration is considerably shorter than the duration which maximises the accuracy of measurement, depending on the cost structure and intended use of the information. In the context of breeding programs, if the resources saved by decreasing test length are used to test related animals and the data from relatives are used in genetic evaluations, the loss of accuracy from using a shorter test duration will be partly compensated by the extra information obtained by measuring an additional related individual. This will mean that the response in accuracy of genetic evaluation to increasing test duration will likely be further flattened, and the optimum duration may be different from that evaluated based on accuracy of phenotypic evaluation alone. These factors should be considered when assessing optimum test duration, and recommendations base on biological parameters alone, such as the present study, should be considered as the maximum test duration required rather than the optimum duration in economic terms.

5. Conclusions

The duration of performance tests for feed intake, average daily gain, feed conversion ratio and residual feed intake could be shortened from 112 days to 70–84 days with very little decrease in accuracy of the test. This would result in considerable savings in
the cost of the performance tests. Fixed testing facilities would have a higher annual test capacity using a shorter duration test, and more test places would be available during times of peak demand under production systems with seasonal calving. There is little evidence to suggest differences between genotypes in the duration of performance test required to accurately measure these traits.

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