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MEASUREMENT OF EFFICIENCY OF FEED UTILISATION IN BEEF CATTLE

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SUMMARY

Feed intake data from 108 yearling bulls were analysed to compare gross efficiency and residual feed intake as measures which can be used to identify individuals which utilise feed more efficiently. Weight maintained accounted for a large amount of the variation in feed intake, while weight gain accounted for a relatively small proportion. Feed intake and residual feed intake measured over a 4 week period were moderately repeatable, but repeatability of weight gain and gross efficiency were low. Gross efficiency and residual feed intake were poorly correlated. The higher repeatability of residual feed intake than gross efficiency suggests that this is a more useful measure of efficiency.
Keywords: efficiency, residual feed intake, gross efficiency, beef cattle.

INTRODUCTION

Recently much attention has been focussed on the efficiency of feed utilisation in beef production, and the effects of selection for growth. In order to examine variation in efficiency an appropriate measure of efficiency is required. The most common measure of efficiency of feed utilisation is that of gross efficiency which is the ratio between feed inputs and production output. For meat production systems gross efficiency is commonly expressed as the ratio of feed intake to liveweight gain. While gross efficiency is a useful measure for nutritional studies using uniform genotypes, it has been shown that gross efficiency is largely determined by growth rate and maturity patterns (Salmon *et al.* 1990) and is not a useful measure for comparisons between genotypes. Gross efficiency is highly correlated with growth rate and hence favours large genotypes with high growth rates. However, these larger genotypes have higher maintenance requirements at maturity which is important in beef production systems where over 50% of the feed required goes toward maintaining the breeding herd (Montano-Bermudez *et al.* 1990). Maintenance requirement at maturity is not accounted for by gross efficiency measured on growing animals. Gross efficiency, therefore, may not be an appropriate measure for comparing feed utilisation efficiency of individuals when considered in the context of an entire production system where both growing and mature animals are fed.

An alternative measure of feed efficiency is the concept of residual feed intake, first suggested by Koch *et al.* (1963). Residual feed intake is calculated as the deviation of the observed feed intake of an individual from that predicted using a model of feed intake. An individual with a negative residual feed intake has consumed less feed than predicted by the model and is thus more efficient than the population average. The model used to predict feed intake can be formulated by adjusting the population feed intake data for any factor which may affect feed intake, such as weight gain and weight maintained. Hence residual feed intake reflects the variation in individual feed intake which is not explained by the model used. Although some of this variation is random, it has been shown to be moderately heritable (eg. Korver *et al.* 1991).

MATERIALS AND METHODS

This study utilises data collected on 108 Angus bulls during 1970 and 1972 at the Trangie Agricultural Research Centre. The bulls were born over a period of 3 months and reared together until weaning, after which they were individually fed for 4 to 5 months. The bulls were kept in groups of 5 in a yard with constant access to water but not feed. Twice daily the bulls were put in individual pens for 2 hours and feed was offered *ad libitum*. The amount of feed consumed by individual bulls during each period was recorded. The ration fed varied slightly between years, but a roughage to concentrate ratio of 2:1 was maintained. The ration was formulated to provide 9.5% crude protein and 65% digestible dry matter. Liveweight of the bulls was measured after an overnight fast at weaning and every 4 weeks thereafter during the experimental period.

Data consisting of 4 consecutive feeding periods of 4 weeks each were used. The total feed intake for the period as well as the weights of the bulls at the beginning and end of each period was recorded. Weight at the end of the fourth period was not measured at the exact time as feed, and was adjusted accordingly. Mean (± sd) weight and age of the bulls at the beginning of period 1 was 276 ± 26 kg at

260 ± 18 days in 1970 and 231 ± 22 kg at 255 ± 13 days in 1972.

Feed intake during each period was modelled by general linear regression (Genstat 1987). Effects of year of birth, age at the start of period 1, weight maintained (estimated as the average of weights at the start and end of the period) and weight gain during each period were included in the model. Residual feed intake is the error term in the feed intake model. Gross efficiency was calculated as feed intake per unit weight gain. Correlations were calculated after adjusting for the effects of year of birth and age at the start of period 1. The repeatability of each trait measured over 4 weeks was estimated from variance within and between animals by fitting the effect of individual animals to data which consisted of 4 measurements per individual.

RESULTS

Results from the feed intake model are shown in Table 1. Weight maintained accounted for a large percentage of the variation in feed intake in all periods, while weight gain accounted for a relatively small proportion. When weight gain was fitted to the model before weight maintained it accounted for 4.3, 10.5, 1.3 and 1.9% of the variation in periods 1 to 4 respectively. Residual variation in feed intake was 10 to 17%.

Table 1. Percentage variance accounted for by terms in the model of feed intake

Source[A]	Period 1	Period 2	Period 3	Period 4
Year of birth	37.7***	36.6***	51.5***	57.5***
Age at period 1	9.1***	15.9***	12.0***	8.5***
Weight maintained	33.0***	29.0***	23.8***	20.8***
Weight gain	3.2***	2.2***	0.0	2.9***
Residual feed intake	17.0	16.4	12.7	10.3
Residual degrees of freedom	95	99	101	99
Total sums of squares	90810	99443	110279	142413

[A]Each term accounted for 1 degree of freedom. Terms in the model were fitted sequentially.
*** $P < 0.001$.

Table 2. Correlations between feeding periods

Periods	Feed intake	Weight gain	Gross efficiency	Residual feed intake
1 and 2	0.82	-0.15	-0.20	0.47
2 and 3	0.86	-0.08	-0.06	0.61
3 and 4	0.86	-0.83	-0.20	0.59
1 and 3	0.74	-0.06	-0.14	0.22
2 and 4	0.79	0.14	0.07	0.48
1 and 4	0.66	0.09	0.05	0.14

Correlations between feed intake measured in different periods are shown in Table 2. The high correlations observed indicate that feed intake over a 4 week period was a good indicator of feed intake in other feeding periods, which agrees with the moderate repeatability calculated for feed intake. Correlations of weight gain between periods (Table 2) were generally low, except for that between periods 3 and 4. Repeatability of weight gain was low (Table 3), hence weight gain during a 4 week period was a poor indicator of weight gain in other periods.

Correlations of gross efficiency between feeding periods (Table 2) were low, indicating that gross efficiency during a 4 week period showed little relationship with that observed during other periods. This was also shown by the low repeatability of gross efficiency (Table 3). The correlations of residual feed intake between feeding periods are given in Table 2. The correlations between adjacent periods were high, with lower correlations observed between periods separated by a longer interval. The repeatability

of residual feed intake was moderate.

Correlations between traits measured over the full 16 weeks of feeding are shown in Table 3. Residual feed intake showed no correlation with weight maintained and weight gain which was expected as these factors were included as adjustments in the model used for calculation of residual feed intake. Residual feed intake was poorly correlated with gross efficiency.

Table 3. Repeatability and correlations between traits

	Repeatability	Feed intake	Weight gain	Weight maintained	Gross efficiency	Residual feed intake
Feed intake	0.69	1.00				
Weight gain	0.09	0.56	1.00			
Weight maintained	-	0.87	0.47	1.00		
Gross efficiency	0.25	0.23	-0.63	0.21	1.00	
Residual feed intake	0.56	0.45	0.00[A]	0.01[A]	0.41	1.00

[A]The correlation of residual feed intake with weight gain and weight maintained is expected to be zero as these factors were included in the model from which residual intake was derived.

DISCUSSION

Feed intake

The feed intake of the bulls in this experiment was not truly *ad libitum*, as bulls did not have access to feed for 24 hours of the day. Consequently, variation in feed intake may have been reduced. This may mean that the high correlations between periods of feed intake (0.66 to 0.86) are an artefact of the feeding regime and not a true reflection of voluntary feed intake. However, despite this concern the data indicated that individuals with high feed intake during a 4 week period tended to have high feed intakes in other periods. Results from the model of feed intake suggest that requirements for maintenance had a larger influence on feed intake than requirements for growth, which is in agreement with the correlations observed. The relatively large influence of weight maintained on feed intake is the most probable cause of the high repeatability (0.69) of feed intake.

*Comparison **of** gross efficiency and residual feed intake*

The high correlation (-0.63) between weight gain and gross efficiency suggests that it was variation in weight gain between periods which was mainly responsible for the low correlations of gross efficiency between periods. High phenotypic and genetic correlations between weight gain and gross efficiency have been observed by others (eg. Brelin and Branning 1982). This illustrates the important difference between gross efficiency and residual feed intake as measures of feed efficiency, as residual feed intake is independent of weight gain and body weight. However, residual feed intake may not be independent of stage of maturity. The relationship between residual feed intake and stage of maturity was unable to be tested in these data as it was not possible to estimate the mature weights of the bulls.

The low correlation (0.41) between gross efficiency and residual feed intake means the ranking of individuals for efficiency is likely to differ between the 2 measures. The higher repeatability of residual feed intake than gross efficiency suggests that residual feed intake may be a more useful measure of efficiency for comparing efficiency between individuals.

*Repeatability **of residual feed intake***

A decrease in correlations of residual feed intake between measurements separated by a longer interval was also observed in laying hens by Bentsen (1983) and Luiting (1991) when residual feed intake was calculated on 4 week periods over a total period of *50* and 44 weeks respectively. This suggests that residual feed intake is repeatable over a short period, but changes in the ranking of individuals for residual feed intake may occur over longer periods. Changes in relative efficiency between individuals may be a function of different maturity patterns of individuals, with relative changes in body composition, etc, which may influence the efficiency of individuals. Alternatively, the changes in residual feed intake may reflect changing emphasis in nutrient partitioning and differing physiological

processes as an animal matures and a greater proportion of the available energy is directed towards maintenance of body functions, rather than accretion of protein or fat. This may be important if residual feed intake was to be used as a basis for selection, as residual feed intake measured at different stages of maturity may reflect different genetic variation. A high genetic correlation between residual feed intake measured on young animals and mature animals is desirable so that selection decisions made on young animals will lead to genetic gains in the efficiency of mature animals.

The moderate repeatability estimate for residual feed intake (0.56) indicates that residual feed intake measured over a 4 week period may be a useful basis for selection of animals for greater feed efficiency. However, if residual feed intake rankings measured on yearlings and mature animals differ, the stage of maturity at which residual feed intake is measured should be considered when developing breeding objectives. Data collected over 16 weeks on yearling cattle is insufficient to make conclusions about changes in residual feed intake occurring over a lifetime, and so further investigation into the genetic basis and the repeatability of residual feed intake is required.

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