MODELLING FEED INTAKE AND EFFICIENCY IN FEEDLOT CATTLE

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SUMMARY

Preliminary results are presented for growth, feed intake and feed efficiency of 1165 feedlot-finished cattle. When intake is modelled as a function of an animal's metabolic weight and weight gain, more variation is explained if gain is estimated (for the period intake was measured) by modelling growth for most of the time animals were in the feedlot. This approach also leads to partial regression coefficients for weight and weight gain which are closer to values calculated from nutritional requirements for maintenance and gain. However, even using modelled gain, the partial coefficients for weight were approximately twice as high as those based on maintenance needs. Unless weight gains can be measured very accurately, eg by automatic weighing, or by a long test period, it may be advisable not to draw any conclusions about the efficiency of an individual animal. Preliminary estimates of genetic correlations for intake, weight, weight gain, fatness and feed efficiency, presented in a companion paper (Robinson *et al.* 1999) may help industry to devise appropriate strategies for genetic improvement.

Keywords: Beef cattle, feed intake, weight gain, feed efficiency

INTRODUCTION

Feed is a major cost in the production of grain-fed beef. Measurement of feed intake and feed efficiency is therefore an important part of the CRC research program. The aim has been to measure feed intake on all CRC core cattle finished at the Tullimba feedlot near Armidale. With 16 automatic feeder (**AF**) pens accommodating up to 12 animals, most groups of animals could be measured for only 50 days, including time needed to adapt to the feeders. Based on an analysis of 308 steers, Robinson *et al* (1997) suggested that accuracy of feed efficiency measurements could be increased by modelling weight for the entire time animals spent in the feedlot and using the modelled growth curve to estimate weight gains while in the AF pens. Results are presented here for intake and growth of 1,165 animals, confirming the benefits of modelled gain. Relationships between intake, metabolic weight and gain and values derived from nutritional requirements are also discussed.

MATERIALS AND METHODS

Data. Feed intake measurements were available on 386 steers and 121 heifers of tropically adapted breeds plus 658 steers of temperate breeds finished at Tullimba between February 1996 and January 1999. Animals were finished for either the domestic market (**D**; 400 kg liveweight; feedlot entry 300 kg), Korean (**K**; 520 kg liveweight; feedlot entry 400 kg) or Japanese markets (**J**; steers only; 600 kg liveweight; feedlot entry 400 kg). Further details of the breeds and source herds of these animals are given by Robinson *et al* (1999). Table 1 shows numbers of animals by market, breed type and sex, as well as mean weights, intakes, weight gains and fatness measurements. It can be seen that growth rates in kg/day were generally lower for older cattle destined for Korean and Japanese markets.

Weight modelling. Weight was recorded at approximately fortnightly intervals while the animals

*AGBU is a joint institute of NSW Agriculture and the University of New England were in standard pens at Tullimba and at weekly intervals while the animals were in the AF pens. Correlation matrices of weights over time revealed the first two weighings after arrival at the feedlot were somewhat atypical, in that they had lower correlations with the subsequent weights. The first two weeks in the AF pens also had lower correlations with the previous and following weights, suggesting the move to AF pens and learning to use the feeders also caused some disruption. Whenever there were adequate remaining data, the first few atypical weighings were therefore excluded from the modelling process.

Table 1. Numbers of groups, animals, trait means plus variances from growth models

Market & sex	No of animals	No of groups tested	Mean wt[1] during test (kg ± SD[2])	Pooled resid var[3] wt mods	Pooled AR param[3]	Mean intake[1] (kg/day)	Mean gain[1] (kg/day)	Rump fat (mm)	Rib fat (mm)	IMF (%)[4]
Temperate breeds (steers only)										
Domestic	75	1	407 ± 39[2]	137	.51	13.3 ± 1.6[2]	2.0 ± .40[2]	7.8	7.2	3.7
Korean	337	4	496 ± 48	93	.31	13.1 + 1.5	1.6 ± .35	11.8	9.3	5.6
Japanese	246	5	564 ± 52	79	.9	12.8 ± 1.6	1.3 ± .32	13.9	13.7	7.6
Tropical breeds										
D - heif	69	2	374 ± 52	39	.7	11.6 ± 2.0	1.5 ± .38	9.1	5.1	3.0
D - steer	63	2	388 ± 58	34	.12	11.8 ± 1.8	1.5 ± .41	6.3	3.6	2.3
K - heif	52	1	479 ± 57	80	.34	12.5 ± 1.8	1.4 ± .45	11.7	6.3	-
K - steer	173	5	490 ± 62	79	.17	12.4 ± 2.1	1.2 ± .42	8.8	6.0	3.9
J - steer	150	6	519 ± 64	69	.26	11.3 ± 1.0	1.1 ± .35	10.1	7.5	5.3

[1]Excludes the first 2 weeks in feeders. [2]Means ± SD, pooled over test groups. SD for gain is for actual, not modelled gain. [3]Pooled pooled autoregressive (AR) parameter ρ and pooled error variance from the weight models and. [4]Intra-muscular fat (*longissimus* muscle, 12/13 rib).

Each group of animals was analysed separately using ASREML (Gilmour *et al.* 1998). Fitted as fixed terms were: an overall linear/quadratic growth curve for the whole group, and linear and quadratic effects of age at first weighing. Random terms were fitted for herd and date of weighing. Random quadratic regressions (modelling departures from the overall fixed growth curve) were also fitted for the different grow-out nutritions, and for each individual animal. The error was modelled either as an autoregressive (AR) process ($\eta_{i+1} = \rho\eta_i + e_{i+1}$), or as a power function, a generalisation of the AR process to allow for differing numbers of days between measurements (Gilmour *et al.* 1998). This error structure was chosen to accommodate longer term errors, as well as short term variation such as errors in measuring weight, variability in the weight of an animal over the course of a day and deviations from the animal's typical feeding pattern. The AR parameter ρ (correlation between successive measurements) allows for longer term departures from a typical growth pattern, such as illness or changes in eating behaviour which affect more than one weight measurement.

All outlying observations from the fitted curves were carefully examined. Feed intake, if recorded, was checked to ensure the animal was eating normally. Sudden and inexplicable decreases or increases in an animal's weight for just a single weighing were considered to be recording errors and so omitted from the analysis. Loss of weight associated with reduced feed intake was noted, but retained. Residual and AR variances from the weight models are shown in Table 1. The pooled residual variance of modelled weight for all animals was 78 kg^2. This represents the mean variance of an individual weight measurement. The variance of a difference between two weights is therefore 156 kg^2. Expected weight gain over 50 days at the average of 1.4 kg/day is 70 kg, or 49 kg excluding the first two weeks (during which animals learn to adapt to the automatic feeders), as atypical. Thus measurement errors of weight gains are substantial, compared with the size of the gains.

Feed efficiency. Net or residual feed intake (**RFI**; kg/day) was calculated by fitting the model: Intake = intercept + metabolic weight + weight gain + RFI (1) to data from each group of animals tested. Intake and weight gain were measured in kg/day; metabolic weight was calculated as mean test weight to the power of 0.73. RFI was defined as the residual or error term from this equation. To compare the efficacy of using modelled vs actual weight gains in this equation, estimates of RFI were calculated using both actual (ie difference between first and last weighings) and modelled weight gains for the period animals were in the AF pens, excluding the first two weeks.

Comparison with Reference Equations. SCA (1990) published equations to estimate intake based on energetic requirements for maintenance and weight gain (see appendix of the companion paper). Residual feed intake (**RFIT**) was also calculated as the difference between the intake of each animal and its requirement based on these equations. The partial regression coefficients implied by the published equations are given in Table 2. The equations use metabolic weight, expressed as mean test weight to the power of 0.75. For this reason, when re-expressed in terms of weight to the power of 0.73, instead of being constant, they decrease slightly as weight increases.

RESULTS

Table 2. Mean intercepts and partial regression coefficients for mean test weight to the power of 0.73 and weight gain for the time in the AF pens (excluding the first 2 weeks) for a) modelled gains and b) actual gains, compared with published values (Australian Agric. Council, 1990)

Market	Modelled gain				Actual gain				Published relationship			
& sex	Int[1]	$Wt^{0.73}$	Gain	R.var[2]	Int[1]	$Wt^{0.73}$	Gain	R.var[2]	Int[1]	$Wt^{0.73}$	Gain	R.var[2]
Temperate breeds (steers only)												
Domestic	-16.54	0.14	10.61	1.34	-1.63	0.19	-0.01	1.56	-1.17	0.07	4.71	5.24
Korean	-3.08	0.12	3.25	0.83	-2.23	0.14	1.45	1.00	-1.33	0.06	5.14	2.70
Japanese	-4.82	0.11	4.95	0.71	-4.83	0.15	1.97	0.92	-0.55	0.06	5.35	2.05
Tropical breeds												
D - heif	-6.27	0.18	2.74	0.64	-5.95	0.21	1.58	0.70	-0.28	0.06	4.90	2.31
D - steer	-2.14	0.13	2.68	0.86	-1.73	0.14	1.85	0.80	0.23	0.06	4.52	2.20
K - heif	-2.03	0.11	3.62	0.63	-3.86	0.15	1.75	0.77	-0.01	0.06	5.39	3.55
K - steer	-1.41	0.09	4.53	1.23	-3.72	0.15	1.58	1.59	1.10	0.06	5.06	3.64
J - steer	-3.18	0.11	3.60	0.80	-4.90	0.15	2.01	1.01	0.36	0.05	5.18	1.90

[1]Int=mean(intake - $Coeff_w$*$Wt^{0.73}$ - $Coeff_g$*gain) for each group, where $Coeff_w$ and $Coeff_g$ are the partial regression coefficients for metabolic weight and gain respectively. [2]R.var = Variance of Residual Feed Intake, calculated using modelled gain, actual gain or the published relationship.

Mean values for intercepts and partial regression coefficients for metabolic weight and gain are shown in Table 2, as well as values based on energetic requirements. As noted earlier, the difference between two weight measurements entails substantial error (average variance 156 kg^2, equivalent to an error SD of 0.36 for actual gain measured in kg/day over 35 days). The least squares procedure for fitting an equation, y = const + βx + error (2), produces an unbiased estimate of the slope, β, only if, as in equation (2), the error term applies to measurement of y, but x is measured without error. If, however, we can measure only an errored version, x + e, of x (with errors e uncorrelated with x), then β is biased downward by a factor var(x)/var(x + e). If e is large compared with the variation in x, the former may dominate the estimate, resulting in a lower estimate than the true value. In contrast, the variance of RFIT, which is based on energetic requirements, is inflated by measurement errors in gain. The coefficient for gain in the published relationship is approximately 5 (Table 2). A measurement error with SD of 0.36 will therefore inflate the variance of RFIT by $(5*0.36)^2 = 3.2$. This is substantially higher than the estimated variation in residual feed intake (Table 2), suggesting that RFIT is dominated by measurement error (noise) rather than signal (actual weight gain).

Use of a relatively short test period was essential in the case of CRC cattle to enable all animals to be tested and hence obtain the best estimates of genetic parameters. Consequently, estimates of gain were highly inaccurate, resulting in lower estimated coefficients for gain in equation (1) than implied by the amount of energy required for deposition of fat and protein (Table 2). This was particularly true for actual gain, calculated as the difference between start and end weights. In general, faster growing animals in any intake group are likely to be heavier, resulting in a positive correlation between weight and gain. This causes an upward bias in the partial regression coefficient for metabolic weight to compensate for the downward bias in the coefficient for gain.

This effect is demonstrated by the group of temperate breed steers finished for the domestic market, tested in October and November 1996. Many animals were weighed only four times while in the AF pens. Ultrasound scans were taken at the same time as the exit weight, resulting in a variable time off feed before measuring weight. This increased measurement error resulted in a partial regression coefficient of zero for gain and, for metabolic weight, a coefficient 2.8 times the theoretical value. The correlation between actual weight gain and intake was -0.03. In contrast, the correlation between modelled gain and intake was 0.56, demonstrating the power of the modelling to overcome measurement errors in the final weighing. However, the modelling process, which involved fitting random regression curves for each animal may "shrink" the variance between animals, making it necessary to compensate by inflating the estimate of the partial regression coefficient for gain.

Use of a relatively short testing period, as was necessary in the CRC to enable all animals to be tested, has highlighted the effect of accuracy of measuring weight gain on estimation of feed efficiency. However, even for a 71 day test in which gain is estimated by fitting a linear regression to fortnightly weighings for each animal, measurement error may be substantial. It can be shown that, for this case, the variance of estimated gain is 0.714V, where V is the variance of the difference between two weight measurements. Our results therefore suggest that measurement error of gain may still be as large as the variation between animals. Consequently, the partial regression coefficient for gain in equation (1) will be biased downward and the coefficient for weight will be higher than in the SCA (1990) equations based on nutritional requirements for maintenance.

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