ESTIMATES OF GENETIC PARAMETERS FOR MATURE WEIGHT FOR BEEF COWS IN THE WOKALUP SELECTION EXPERIMENT

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SUMMARY

Weights of Polled Hereford and 'Wokalup' cows in the Wokalup selection experiment were obtained monthly, with up to 11 years of records per cow available. Mature weights were analysed treating them as repeated records per animal and by fitting a Gompertz growth curve for each animal. Estimates of heritabilities for mature weight were 0.3 to 0.4 for Herefords and 0.5 to 0.6 for Wokalups, and 0.3 for rate of maturation in both breeds. Genetic correlations with cannon bone length at birth were moderate to high, with earlier maturing animals tending to have shorter cannon bones. Implications on selection for mature size are discussed.

INTRODUCTION

An understanding of genetic characteristics of mature weight and maturing rate is central to predicting the outcome of breeding programs aimed at manipulating future relationships among weight, age and fatness in beef cattle. Pitchford (1993) reported that von Bertalanffy, Gompertz and logistic curves overestimated weights at early ages. He suggested the use of a modified Gompertz curve to predict W_t, the weight of an animal at time t, with intercept equal to its birth weight (W_0) which has two biological meaningful parameters, namely the average mature size maintained, A, and the rate of maturation, K:

$$W_t = Ae^{(\ln W_0 - \ln A)e^{-Kt}} \tag{1}$$

Donnelly and Freer (1976) suggested that the use of equations to predict growth rates would be more successful if some predictor of mature size were available. In the 1930s, there had been considerable interest in the use of cannon bone (metacarpal) length for this purpose (Hammond, 1940), because of the extraordinary fact that this bone (plus the associated joints) is 62% of its mature length at birth. By contrast, birth weight is only 6% of mature weight (Pálssen, 1955).

This paper reports a preliminary examination of genetic relationships among these variables measured in the Wokalup selection experiment in which cattle of contrasting maternal influences, mature size and genetic background were selected for increased preweaning growth rate.

MATERIAL AND METHODS

Data originated from the selection experiment conducted at Wokalup in the South West of Western Australia beginning in 1972, selecting since 1978 for increased pre-weaning growth rate in two herds of about 300 cows each. Throughout the experiment, all animals were weighed monthly except during the calving season (May-June). One herd comprised straightbred Polled Herefords, the other a synthetic breed formed by mating Charolais × Brahman bulls with Friesian × Angus or Hereford cows, 'Wokalups' for short. Further details of the experiment, management and environmental condition are given by Meyer *et al.* (1993).

January weights were chosen as representative annual weights for cows. With a Mediterranean seasonal growth pattern of Winter and Spring growth and Summer and Autumn dearth, and weaning taking place in late November or early December, these typically measured cows in their best condition and top weight

No. mature wgt.s	Hereford				Wokalup			
	0	1	2	3	0	1	2	3
No. records	1224	684	546	428	1379	722	571	447
No. animals[a]	1372	901	752	638	1496	918	762	634
No. dams[b]	495	312	243	190	464	264	205	161
No. sires[b]	151	120	108	90	146	113	95	86
A : Mean	466.7	520.3	535.9	544.7	488.5	551.0	568.9	577.7
SD[c]	96.7	66.6	54.4	50.8	108.9	71.3	59.9	54.4
$K \times 10^3$: Mean	7.620	4.587	4.418	4.321	8.356	4.789	4.534	4.434
SD	15.882	0.708	0.531	0.0488	17.132	0.885	0.673	0.613

Table 2: Data structure for A and K

[a]in the analysis, including parents without records
[b]with progeny in the data
[c]standard deviation

in the year. Traits considered were mature weight (MW), treated as a repeated record per animal, cannon bone length (CB), measured at birth, and hip height (HH), recorded at weaning. Furthermore, a Gompertz curve was fitted for each animal as described by Pitchford (1993) yielding A and K (see equation 1) as additional traits. While weight records were available from 1973 until 1990 (inclusively), CB recording was not begun until 1981 and HH was only measured from 1986 onwards. Characteristics of the data structure are summarised in Table 1 for MW (see Table 2 for footnotes) and in Table 2 for A and K. Details for CB and HH are given by Meyer (1995).

Estimates of (co)variance components and genetic parameters were obtained by Restricted Maximum Likelihood fitting an animal model and utilising all pedigree information available. Calculations were carried out using DFREML Version 2.1 (Meyer, 1992).

Age [years]	Hereford			Wokalup		
	3+	4+	5+	3+	4+	5+
No. records	2637	1971	1457	2813	2150	1637
No. cows	692	556	443	721		468
No. animals[a]	980	823	717	1040	883	752
No. dams[b]	412	328	277	420	341	265
No. of sires[b]	136	124	109	137	121	103
MW : Mean	561.5	586.2	598.3	594.7	617.1	627.4
SD[c]	77.8	65.5	62.8	83.0	73.1	70.4

Table 1: Data structure for MW

Fixed effects fitted for MW were age class (in years) and year-paddock of weighing, fitting age of cow (in months) as a linear and quadratic covariable in addition. For A and K, only year of birth and the number of weight records taken as 3-year olds or older were taken into account. Models of analyses for CB and HH were as used by Meyer (1995), i.e. fitted birth type (single vs. twin), sex at weighing, year-paddock and year-month of weighing subclasses as fixed effects, and age of dam and age at weighing (for HH) as a linear and quadratic covariable each.

For MW, residuals between records were considered correlated to allow for permanent environmental effects due to the animal. For A and K, univariate analyses were carried out ignoring and fitting permanent environmental and genetic maternal effects in turn, i.e., following the notation of previous growth traits analyses (Meyer *et al.*, 1993), a simple animal model (Model 1, M1), animal models allowing for permanent environmental effects of dams (Model 2, M2) or maternal genetic effects (Model 3, M3) as additional random effect, and including both types of maternal effects (Model 5, M5) were fitted. In bivariate analyses together with CB and HH, M5 was fitted for A and M2 for K in Herefords, while M1 sufficed for both A and K in Wokalups. As in Meyer (1995), M5 and M2 were fitted for the analysis of CB in Herefords and Wokalups, respectively, and M2 was fitted for HH in both breeds. Direct and maternal genetic effects were considered uncorrelated throughout.

RESULTS AND DISCUSSION

Estimates from univariate analyses of MW considering successive subsets of the data are given in Table 3. The phenotypic variance (σ_P^2) was reduced when including records for 3-year-olds even though the model included age effects. Thus further analyses of MW considered only records taken at 4 years of age or

Min. no. wgt.s	Hereford				Wokalup			
	0	1	2	3	0	1	2	3
A σ_P^2	3349	2315	2132	2127	4449	2966	2859	2815
h^2	0.35	0.56	0.51	0.51	0.38	0.60	0.60	0.77
s.e.	0.07	0.09	0.09	0.10	0.07	0.09	0.10	0.12
K σ_P^2	227.2	0.281	0.175	0.160	269.9	0.316	0.206	0.182
h^2	0.00	0.48	0.33	0.37	0.05	0.32	0.28	0.32
s.e.	-	0.09	0.09	0.10	0.06	0.09	0.08	0.11

Table 4: Univariate estimates for A and K

later. Repeatabilities for both breeds were similar, but the relative importance of additive genetic effects and permanent environmental effects due to the animal (p^2) differed markedly. As in previous analyses of growth traits (Meyer *et al.*, 1993), heritabilities (h^2) and σ_P^2 were higher in Wokalups than in Herefords. Conversely, estimates for p^2 were about twice as high in Herefords than in Wokalups (Second lines in Table 3 giving approximate standard errors for h^2 and p^2, respectively). Results from univariate analysis under M1 for the A and K are in Table 4. Again various subsets of the data were considered. Increasing means in Table 2 showed that the number of MW records taken at 3 years or older affected the curve fitted markedly. As estimates of σ_P^2 decreased considerably until at least 2 such records were available, this restriction was imposed for subsequent uni- and bivariate analyses.

Age	Hereford			Wokalup		
	3+	4+	5+	3+	4+	5+
σ_P^2	3189	3400	3405	4354	4461	4428
h^2	0.31	0.30	0.33	0.48	0.49	0.48
	0.06	0.07	0.09	0.06	0.08	0.10
p^2	0.31	0.37	0.33	0.13	0.17	0.19
	0.06	0.07	0.08	0.05	0.07	0.09

Table 3: Estimates for MW

Model	Hereford			Wokalup	
	M2	M3	M5	M2	M3
A σ_P^2	2129	2120	2122	2841	2853
h^2	0.47	0.36	0.39	0.59	0.54
m^2	-	0.17	0.12	-	0.06
c^2	0.15	-	0.06	0.00	-
log L	2.44	2.92	3.08	0.00	0.35
K σ_P^2	0.1759	0.1761	0.1761	0.2061	0.2065
h^2	0.32	0.27	0.32	0.28	0.28
m^2	-	0.11	0.00	-	0.00
c^2	0.15	-	0.15	0.00	-
log L	2.02	1.08	2.02	0.00	0.00

Table 5: Estimates of maternal effects for *A* and *K*

Table 5 summarises estimates from univariate analyses of *A* and *K* including maternal effects, showing the increase in log likelihood (L) over that under M1. For Wokalups, maternal effects on the parameters of the growth curve were unimportant, while they affected both *A* and *K* significantly for Herefords. For these, only maternal environmental effects (c^2) were important for *K*, while maternal genetic effect (m^2 : maternal heritability) appeared to have a bigger effect on *A* than the former. Hence in subsequent bivariate analyses, M1 was fitted for both *A* and *K* for Wokalups and M5 and M2 respectively for Herefords.

Numbers of animals in each bivariate analysis (including parents without records) and with records for each combination of traits (Trait 2 = MW, *A* or *K*) are given in Table 6. With recording of hip height at weaning not begun until late in the experiment, only very few animals had records for mature weight and HH.

Estimates of correlations from individual bivariate analyses are given in Tables 7 and 8 (r_A : direct genetic, r_M : maternal genetic, r_C : maternal environmental, r_E : residual, and r_P : phenotypic correlation). In both breeds, estimates of r_A between mature weight, by either measure, and CB were high. For HH, r_As in Wokalups were of similar magnitude, while there appeared to be little genetic association in Herefords. This makes a case for using cannon bone length as the correlated measure of choice for mature size as well as maturing rate, rather than hip height as is industry

Trait 1	CB	HH	CB	HH
	Heref.		Wokal.	
No. anim.s	2506	1561	2613	1669
- tr. 1 only	1645	712	1725	752
- tr. 2 only	284	501	324	527
- both tr.s	262	45	247	44

Table 6: No.s in bivariate analyses

practice.

Trait 1	CB			HH		
Trait 2	MW	*A*	*K*	MW	*A*	*K*
			Hereford			
r_A	0.75	0.81	-0.63	-0.25	-0.01	0.05
r_M		0.65				
r_C		1.00	-0.68		1.00	-0.17
r_E	-0.05	-0.21	0.20	0.58	0.45	0.25
r_P	0.20	0.30	-0.15	0.29	0.28	0.15
			Wokalup			
r_A	0.64	0.70	-0.62	0.63	0.74	-0.57
r_E	0.05	0.20	0.02	-0.01	0.19	0.26
r_P	0.33	0.46	-0.22	0.35	0.41	-0.10

Table 7: Correlation estimates with CB and HH

With the current industry focus on feed-lot growth and carcass quality, the issues of mature size and maturing rate are central to economic success. Specifications for different markets (and hence for different product values) are strongly dominated by relationships among age, weight and fatness - all directly related to potential mature size and maturing rate on one hand and nutritional status on the other. Correctly matching maturity and nutrition is the key to future success in the industry. Additional traits such as marbling and colour, although important for some markets, are secondary to these. Traditionally, the industry has thought in terms of breeds when considering altering mature size or maturing rate. However, if a breed has a high frequency of some other desirable trait such as marbling, then this study shows that within-breed selection for altered mature size or maturing pattern is possible.

CONCLUSIONS

Estimating mature size using the two-parameter Gompertz curve gives h^2s for mature size which are higher than those using repeated measures for MW. This suggests that the Gompertz approach accounts better for environmental variation. The high genetic correlation between *A* and CB makes the latter an ideal indirect and early predictor of breeding value for mature size, and, together with h^2 estimates for CB of 0.29 (Herefords) and 0.44 (Wokalups) (Meyer, 1995), suggests that birth may be the best time to estimate skeletal size. As direct observations of mature size necessitate waiting until animals are 3 or 4 years of age, a good genetic indicator of mature size, which is as easily measured as cannon bone length, is potentially very valuable. Perhaps it is time to consider a genetic evaluation

	Hef.	Wok.
r_A	-0.53	-0.78
r_C	-0.39	
r_E	-0.64	-0.44
r_P	-0.54	-0.56

Table 8: *A* and *K*

for mature size using some of these relationships (including CB). Although, the genetic correlation between maturing rate and mature size was moderate to high and negative, there remains scope for "bending" the growth curve.

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