DIRECT, MATERNAL AND CYTOPLASMIC GENETIC EFFECTS ON DAILY GAIN FROM BIRTH TO 45 DAYS OF BEEF CALVES

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Summary

Variance components were estimated for calf daily gain from birth to 45 days of age in small (S), medium (M) and large (L) lines of beef cattle. Analyses involved records collected on 682 (S), 510 (M) and 228 (L) calves in Iowa, USA from 1978 to 1986. Cytoplasmic lines were determined based on the foundation female in the maternal lineage of each animal. Data were analyzed separately by size line using a derivative free restricted maximum likelihood procedure under an animal model including additive direct (a), additive maternal (m), cytoplasmic lineage effects and covariance (a, m). The heritabilities for direct and maternal, and the cytoplasmic effects, were 0.13, 0.35 and 0.00 for S, 0.14, 0.32 and 0.00 for M, and 0.05, 0.33 and 0.03 for L. Genetic correlations (a, m) for S, M and L were −0.33, −0.57 and −1.00, respectively. The maternal genetic effect was the most important for calf growth between birth and 45 days of age and cytoplasmic variances were not important in any line.

(**Key Words**: Daily Gain, Maternal Effects, Cytoplasmic Effects, Genetic Variance, Animal Model, Beef Cattle)

Introduction

It is well known that a maternal effect is important for preweaning growth in beef cattle. The direct and maternal heritabilities for birth and weaning weights have been reported by many researchers (Bertrand and Benyshek, 1987; Cantet et al., 1988; Arthur et al., 1989; Garrick et al., 1989). The milk yield of cows explained about 80% of the variation of calf daily gain from birth to 6-8 weeks of age in beef cattle, though milk yield did not affect calf daily gain just before weaning (Shimada et al., 1988). However, there are few published estimates of genetic parameters for early calf growth.

Recently, mitochondria, which contain DNA (mtDNA) and are maternally inherited in mammals, attracted notice as the source of a cytoplasmic genetic effect (Kennedy, 1986; Tess et al., 1987). Latest studies show little influence of cytoplasmic genetic effects on calf growth and milk production in cattle (Reed and Van Vleck, 1987; Tess et al., 1990; Northcutt, 1990). However, Brown et al. (1989) found a relationship between restriction fragment length polymorphism of mtDNA and milk fat percentages in Holstein cows. Calf daily gain in the early stage of growth could be influenced by cytoplasmic genetic effects since it depends on milk yield.

The objectives of this study were to evaluate direct and maternal genetic effects on calf daily gain from birth to 45 days of age, and to see if a cytoplasmic genetic effect could be demonstrated.

Materials and Methods

The Iowa State beef cattle breeding project was initiated in 1977 to develop three size lines using Jersey, Angus and Simmental sires. The small, medium, and large lines were replicated at two research farms (McNay and Rhodes). Breed composition of dams and the development of the three synthetic lines were described in previous papers (Buttram and Willham, 1989; Northcutt, 1990). Data from the McNay herd, operated under a fall calving program in which calves were weaned at 45 days of age, were used in this study. Table 1 shows the number of animals.

Variance components were estimated for adjusted daily gain from birth to 45 days of age using a derivative-free restricted maximum likeli-

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TABLE 1. THE NUMBER OF ANIMALS

Item	Lines		
	Small	Medium	Large
Calf	682	510	228
Sire	72	85	67
Dam	261	205	97
Base[a]	133	147	94

[a] Parents of the first generation.

hood (DFREML) using an animal model (Meyer, 1989). Data were analyzed separately by size line. The mixed model included additive direct, additive maternal, cytoplasmic genetic effects, covariance between direct and maternal genetic effects and residual error as random effects. Fixed effects included were calf birth year, sex of calf and age of dam (2, 3, 4, 5 years and older). A cytoplasmic line was defined as all animal with a common cytoplasmic source. Pedigree information was traced back to their cytoplasmic origin. The number of cytoplasmic lineages for small, medium and large lines were 69, 63 and 32, respectively. Heritability estimates and the genetic correlation between additive direct and maternal effects were calculated from the (co) variances components. The convergence criterion was 1×10^{-10} for all analyses. Starting values for additive direct, additive maternal, cytoplasmic heritabilities and covariance between additive direct and maternal effects were 0.40, 0.10, 0.15 and −0.05, respectively.

Results

The means, standard deviations and ranges for calf daily gain are shown in table 2. The differences in mean daily gain between small and medium, and medium and large lines were about 0.05 kg. Coefficients of variation were 25% and 26% in small and medium lines, and 29% in the large line.

TABLE 2. MEAN, S.D. AND RANGE OF RECORDS (kg)

Item	Lines		
	Small	Medium	Large
Mean	0.691	0.757	0.802
S.D.	0.174	0.197	0.231
Min.	0.192	0.202	0.232
Max.	1.200	1.320	1.452

The DFREML procedure performed 224-279 likelihood evaluations to reach the specified convergence criterion. Genetic variances and covariances obtained are shown in table 3. Maternal effects were considerably larger than direct effects, and covariances between these two effects were negative in all three size lines. Cytoplasmic genetic variances were very small except in the large line.

TABLE 3. ESTIMATES OF (CO) VARIANCE COMPONENTS

Variable	Lines		
	Small	Medium	Large
σ_a^2	0.333×10^{-2}	0.423×10^{-2}	0.224×10^{-2}
σ_m^2	0.867×10^{-2}	0.949×10^{-2}	0.143×10^{-1}
σ_{am}	-0.180×10^{-2}	-0.361×10^{-2}	-0.566×10^{-2}
σ_c^2	0.264×10^{-7}	0.355×10^{-8}	0.141×10^{-2}
σ_e^2	0.147×10^{-1}	0.195×10^{-1}	0.312×10^{-1}

Table 4 shows the heritabilities and genetic correlations calculated from (co) variance shown in table 3. Heritabilities for additive direct effect were low, ranging from 0.05 to 0.14, and maternal ones were moderate around 0.33. Genetic

TABLE 4. HERITABILITIES AND GENETIC CORRELATIONS

Effect	Lines		
	Small	Medium	Large
Direct (a)	0.13	0.14	0.05
Maternal (m)	0.35	0.32	0.33
Correlation (a, m)	−0.33	−0.57	−1.00
Cytoplasmic	0.00	0.00	0.03

correlations between direct and maternal effects were negative, ranging from 0.33 to −1.00. Cytoplasmic effects were zero in small and medium size lines, and 0.03 in the large line.

Discussion

Direct and maternal variance components have generally been estimated using variances and covariances between relatives (Willham, 1963; Togashi and Yokouchi, 1982; Cantet et al., 1988) or diallel cross experiments (Arthur et al., 1989). Meyer wrote a set of programs named DFREML for estimating the variance components under an animal model (1989). DFREML used in this study allows the model to include three random effects and a covariance between random effects. It does not use matrix inversion, and is suitable for data analysis from selected herds of a practical size for which pedigree information is known.

Calf weaning weight around 200 days of age has been used as a indicator of maternal ability in beef cattle and many genetic parameters of calf weaning traits have been reported. However, calf daily gain up to two months of age is more related to milk yield of the dam than weaning weight. The importance of milk yield of the dam declines rapidly as the lactation progresses (Clutter and Nielsen, 1987; Shimada et al., 1988). Maternal heritabilities for calf daily gain from birth to 45 days estimated in this study were larger than the direct ones, especially in the large line. Maternal heritabilities for weaning weight around 200 days of age are generally reported to be similar to or slightly larger than direct heritabilities (Bertrand and Benyshek, 1987; Cantet et al., 1988; Garrick et al., 1989). The maternal heritabilities in this study tended to be higher than others in the literature. Togashi and Yokouchi (1982) reported the maternal heritability for calf weight in Hereford increasing from 0.34 at birth to 0.71 at 6 months of age, while the direct heritability was 0.36 at birth and 0.23 at 6 months. The additive direct heritability in the large line was considerably lower than in the other two lines. Northcutt (1990) reported the direct heritability for total preweaning gain in the same herd to be 0.04. The cytoplasmic effect accounted for 3% of the variation in this study. This result might be caused by sampling when this line was initiated or the small number of records due to the lower reproductive rate in the large line (Buttram and Willham, 1989). The genetic correlations between additive direct and maternal effects were all negative. This result is in agreement with published estimates (Bertrand and Benyshek, 1987; Cantet et al., 1988; Garrick et al., 1989).

Recent studies indicate that cytoplasmic genetic effects caused by mtDNA have no significant effects on calf growth in cattle (Reed and Van Vleck, 1987; Tess and Robison, 1990; Northcutt, 1990) and this is confirmed by this study. However, the characteristic of mtDNA inheritance, transferred directly from dam to offspring without Mendelian segregation and recombination, could offer opportunities if its effect is important. There is a need for further research on the cytoplasmic genetic effect in different herds and for clearer definition of maternal lineages.

The result of this study suggests the importance of calf weight around 45 days of age for estimating maternal ability.

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