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Introduction

The phenotype of an individual is the manifestation of that individual's genotype, environment, and the interaction of that genotype and environment. The genotype is attributable to nuclear genetic material equally contributed by the sire and the dam. The *in utero* environment and(or) the genotype of the dam (maternal effects) have long been known to have an influence on fetal and postnatal development. These effects were documented by Walton and Hammond (1938), who described the growth of Shetland pony-Shire horse reciprocal crosses. The physiology of the individual (e.g., enzyme activities, endocrine secretion and function) is the phenotypic expression of that individual's genotype and environment just as much as grossly observed characteristics such as color, height, and weight.

The objective of the present study was to investigate the effects of genotype and prenatal maternal environment on the secretion of two metabolically important hormones [growth hormone (GH) and prolactin (PRL)] and the growth of individual calves of Angus-Red Poll genotype. Through embryo transfer, the confounding of the effects of maternal genetic contributions and prenatal maternal environment was eliminated.

Procedure

Eight full-sib pairs of Angus-Red Poll genotype calves whose gestational development occurred in cows of either the Angus or Red Poll breeds were selected for use in the present study. The eight pairs selected for use in this study represented four pairs with Angus sires and Red Poll dams and four pairs with Red Poll sires and Angus dams (Fig. 1). The male calves were castrated at birth. Three to five days after birth, the calves were removed from their gestational dams and thereafter raised in nursery stalls on milk replacer, thus eliminating the influence of postnatal maternal effects (e.g., lactation) on postnatal performance. The calves were weighed at birth and at an avg age of 150 days, and those weights were adjusted to that age. Average daily gain from birth to 150 days was calculated.

When the calves were 8 to 9 wk of age (60 $\pm$ 1 day of age, mean $\pm$ SE), they were fitted with indwelling jugular cannalae. The following day, blood samples were collected via the cannulae at 15-min intervals for an 8-hr period.

The temporal concentrations of each hormone within each animal were subjected to an algorithmic procedure which defined the secretory pattern in terms of overall mean concentration, baseline mean concentration, number of secretory peaks, and amplitude above baseline of those peaks.

Results

Calves from Red Poll recipients had significantly greater birth and 150-day weights. The genotype effect was not significant for any growth estimate. However, the effects of sex and the interaction of sex with genotype was significant for 150-day wt and birth to 150-day avg daily gain. The interaction of recipient breed and genotype and the interaction of recipient breed and sex were both significant for 150-day wt and avg daily gain.

Prolactin baseline concentration was influenced by genotype ($P < .05$). Sex of calf had a significant effect on basal concentration of GH, amplitude above basal concentration of the GH peaks ($P < .05$), and, thus, on mean GH concentration ($P < .1$) (higher in the castrate males than in females). The interaction of genotype and recipient breed was significant for mean growth hormone concentration and number of growth hormone peaks. The interaction of recipient breed and sex was significant for mean growth hormone concentration.

Discussion

The influences of uterine or prenatal environment (recipient breed) and the interactions of prenatal environment and genotype (sire breed-dam breed combination) and sex accounted for the majority of the significant effects observed. Genotype differences alone accounted for little of the variation in the phenotypic characteristics studied. Thus, differences in maternal genetic contributions between the Angus and Red Poll breeds had little or no effect on most of the parameters estimated.

It has been demonstrated in previous studies that the influences of the maternal genetic contributions or uterine environment, or both, and postnatal maternal effects (e.g., lactational ability) combined have pronounced and permanent influences on the growth and development of the offspring. In those studies, prenatal and postnatal effects were confounded. Through the use of embryo transfer technology, we have separated prenatal maternal effects caused by breed differences in ovum cytoplasm from those caused by breed differences in uterine environment. By removing calves from dams and rearing with milk replacer diet, we have eliminated the confounding postnatal effects of maternal lactational ability.

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Calf No.	Pair	Genotype (Breed of Sire x Breed of Dam) (GT)	Recipient Breed (RB)	Sex (SX)
1	1	Red Poll x Angus	Red Poll	Female
2			Angus	Female
3	2	Red Poll x Angus	Red Poll	Female
4			Angus	Female
9	3	Red Poll x Angus	Red Poll	Female
10			Angus	Female
11	4	Red Poll x Angus	Red Poll	Male
12			Angus	Male
5	5	Angus x Red Poll	Angus	Male
6			Red Poll	Male
7	6	Angus x Red Poll	Red Poll	Male
8			Angus	Male
13	7	Angus x Red Poll	Red Poll	Male
14			Angus	Male
15	8	Angus x Red Poll	Angus	Female
16			Red Poll	Female

Figure 1—Description of calves used in this study. Calves within a pair were full-sibs. At 8 days post-estrus, the embryos were transferred (→) to recipient cows of each breed.

The effect of recipient breed was significant for birth wt, 150-day wt, and GH peaks. The uterine environment provided by Red Poll cows was more favorable for fetal growth and subsequent postnatal growth than the uterine environment of the Angus cows. However, the uterine environment provided by Angus cows allowed the calves they carried to develop with a greater ability to secrete GH episodically. Thus, GH was negatively associated with prenatal and postnatal growth rate. The calves carried by Angus cows or carried by Red Poll cows and derived from Angus ova had more GH secretory peaks. The uterus and maternal placenta have two major roles, nutrition of the fetus and endocrine synthesis and secretion, both of which may be contributing to the differences observed in the present study. Recipient breed (the environmental influence) represents the nutrient availability to the fetus and the maternally determined endocrine environment to which the fetus is exposed. Genotype effects and sex represent genetic influences which determine nutrient requirements of the fetus.

The data presented provide evidence that the phenotypic characteristics of an individual are the result of both genetic and environmental influences in cattle. These data also imply that the environmental influences impinge upon the development of the individual throughout its life. As reported by Walton and Hammond (1938), maternal effects influence the growth of the individual. Maternal effects, such as maternal genetic contributions and prenatal environment, also influenced GH and PRL secretion, particularly GH.