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PRNP Genotype and Sale Price

Associations of prion protein genotype with sale price in a flock of purebred Polled Dorsets[1]

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Summary

The objectives of this study were to determine prion protein (PRNP) genotype frequencies in a flock of Polled Dorsets and to estimate the association of PRNP genotype with the value placed on PRNP genotype by buyers of elite breeding stock. The association between selling price and genotype was determined for 161 sheep. Sale price and 90-d BW were analyzed with a mixed model that included PRNP genotype, year-season of birth, and litter size (90-d BW only) as fixed effects; animal, litter, and error as random effects; and 90-d BW as a covariate (sale price only). The frequencies of R/R (homozygous scrapie resistant), Q/R, and Q/Q (homozygous scrapie susceptible) genotypes were 25 percent, 49 percent, and 26 percent, respectively. The effect of genotype on sale price was highly significant, and buyers of elite breeding stock paid $799 more for R/R individuals than Q/Q individuals. The allele substitution effect for the R allele was $397. Sale prices for Q/Q sheep were significantly associated with 90-d BW and increased approximately $34 for a one kg increase in BW. The effect was not as strong ($22 per kg) and not significant for R/R sheep. Buyers of elite breeding stock are placing a strong emphasis on PRNP genotype relative to performance characteristics, indicating that sheep breeders are engaged in national scrapie-eradication efforts.

Key Words: Dorset, Genotype, Prion Protein, Scrapie

INTRODUCTION

Parry (1979) demonstrated that susceptibility to scrapie could be reduced by genetic selection. Scrapie susceptibility has been linked to polymorphisms in the prion protein (PRNP) gene (Bossers et al., 1996). Variation at codon 171 of the PRNP gene is the major determinant of scrapie susceptibility and the polymorphism resulting in arginine (R) confers scrapie resistance (NIAA, 2004).

Producers might be hesitant to select intensely for scrapie resistance if an unfavorable relationship between performance and PRNP genotype was evident. Several studies have investigated the relationship between PRNP genotype and lamb growth (Brandsma et al., 2004; Alexander et al., 2005; Vitezica et al., 2006), reproduction (Alexander et al., 2005; Vitezica et al., 2006; Casellas et al., 2007), carcass, and other traits (Isler et al., 2006; Sawalha et al., 2007). Most have found minimal evidence that selection to increase the frequency of R will directly compromise important performance traits, but there are exceptions related to litter size (Alexander et al. 2005; Casellas et al., 2007).

There is minimal evidence that selection for PRNP genotype will compromise sheep performance, but it is not clear how much emphasis producers are placing on scrapie resistance in sheep-selection programs. The percentage of scrapie-infected sheep detected by the Regulatory Scrapie Slaughter Surveillance has been steadily declining (APHIS, 2007) and selection for scrapie resistance is likely one factor contributing to that trend. The frequency of R/R was higher in lambs than in ewes in four out of five breeds evaluated (Alexander et al., 2005), and the frequency of the R allele in a French composite breed increased from 2001 to 2003 (Vitezica et al., 2006). However, the frequency of the scrapie-resistant haplotype (ARR) did not increase from 1999 to 2004 in a population of Scottish Blackface (Sawalha et al., 2007). The effect of PRNP genotype on the habits of breeding-stock purchasers would indicate how much emphasis is placed on scrapie resistance, but has not been described.

The objectives of this study were to determine PRNP-genotype frequency in an elite flock of Polled Dorsets and to estimate the association of PRNP genotype with the value placed on PRNP genotype by buyers of elite breeding stock.

MATERIALS AND METHODS

Sheep

All procedures were conducted under approval of the Institutional Animal Care and Use Committee at The Pennsylvania State University (IACUC #22956). A single blood sample was collected by jugular venipuncture into EDTA-coated Vacutainer tubes. Samples were submitted for genotyping to an APHIS-approved commercial laboratory (GeneCheck, Inc., Fort Collins, Colo.). Only genotype at codon 171 was considered, and no distinction was made between the Q, K and H alleles, which are collectively referred to as Q in the present study.

A total of 363 purebred Polled Dorsets from The Pennsylvania State University were genotyped, and 189 were sold in a Penn State production sale. Genotyped sheep sold for an average of $1,280, whereas 39 non-genotyped sheep sold for an average of $1,034. The distribution of sale price was skewed (Figure 1), so the natural log was used to transform sale price into a normally distributed variable. Body weights recorded between 75 d and 105 d were standardized to 90-d BW by FlockMaster for Windows (ABM Computer Systems, Springfield, Mo.). Data from 28 genotyped sheep that did not have 90-d BW were removed, leaving data from 161 sheep for analysis (144 ewes and 17 rams). Twenty-two rams sired the 161 sheep, with the number of offspring ranging from one to 41 per ram. The pedigree file included 419 animals.

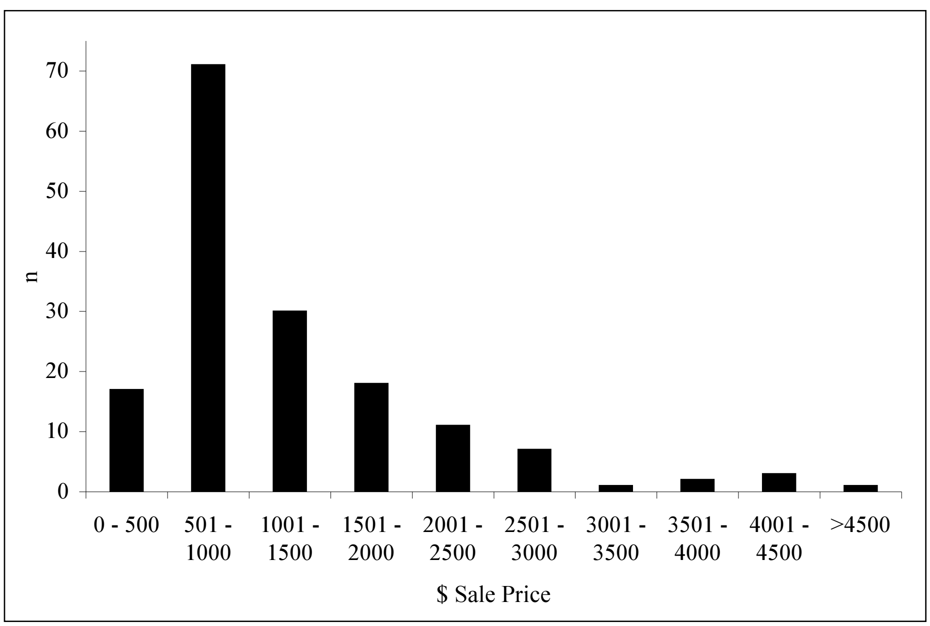
Statistical Analysis

The following animal model was used to analyze sale price in ASREML (Gilmour et al., 2006):

$$y_{ijkm} = YS_i+b_1*BW_{90}+G_j+a_k+l_m+e_{ijkm},$$

where y = the natural log of sale price; YS = fixed effect of year-season of birth i with three birth year groups (≤2003, 2004, and 2005) and two seasons corresponding to spring and fall; b_1 = a regression coefficient for 90-d BW; G = fixed effect of genotype j; a = the random effect of animal k; l = the random effect of litter m; and e = random error. Additionally, 90-d BW was nested within genotype to test for interactions of genotype with BW ($P = 0.009$). Sex ($P = 0.78$), classes corresponding to birth and rearing litter size ($P = 0.098$), and an interaction between genotype and year ($P = 0.56$) were not significant. An analysis of 90-d BW was also conducted to determine the association between 90-d BW and genotype. The model was the same as for sale price,

Figure 1. Distribution of sale price for 161 Polled Dorsets.



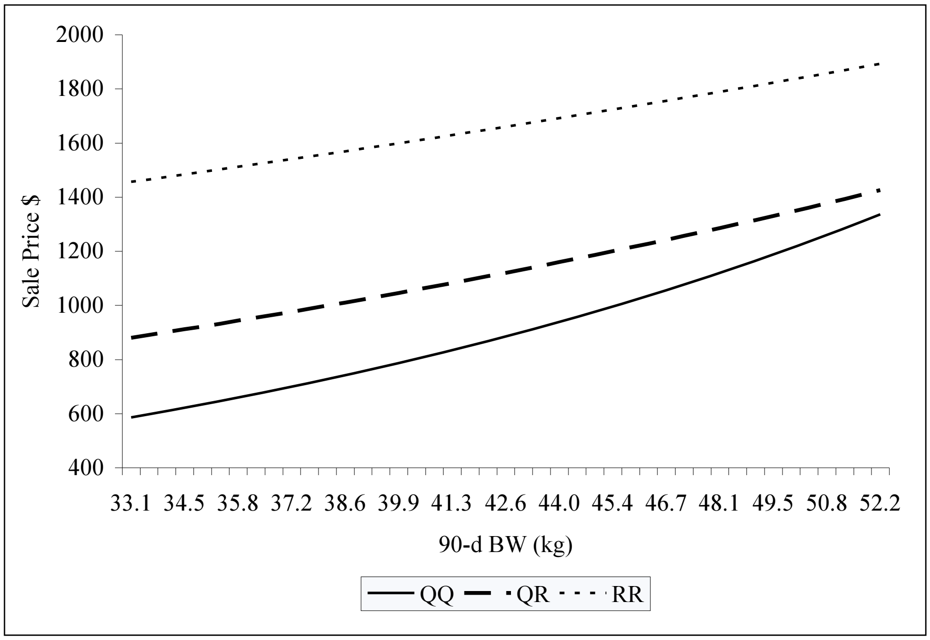
except that 90-d BW was removed as a covariate and the fixed effect for birth and rearing litter size was significant (*P < 0.001*) and included in the model.

The effect of genotype was quantified by generating predicted sale-price means, which are equivalent to least-squares means in ASREML, for genotype and by calculating the substitution effect of the R allele. The R allele substitution effect was:

$$a + (q-p)d,$$

where a = the deviation of the R/R genotype from the homozygote mean; d = the deviation of the Q/R from the homozygote mean; q = the frequency of the R allele; and p = the frequency of the Q allele (Falconer and Mackay, 1996). Sale-price-predicted means from the minimum 90-d BW that was observed in the range of all genotypes (33.1 kg) to the maximum observed in the range of all genotypes (52.2 kg) were plotted to demonstrate the interaction of genotype and 90-d BW.

Figure 2. Trend in sale price for genotype by 90 day body weight (90-d BW).



RESULTS AND DISCUSSION

PRNP Genotype Frequency

Genotype frequencies, predicted-sale-price means, and predicted 90-d BW for PRNP genotype are reported in Table 1. The frequency of the R allele was 49 percent. Selection for PRNP genotype was not practiced prior to sampling and, subsequently, the genotype frequencies appeared to be in Hardy-Weinberg equilibrium. The frequency of the Q allele has been reported to be greater than 50 percent in many populations, which indicates that a large proportion of U.S. and worldwide sheep populations are at risk of contracting scrapie if exposed to scrapie-infected animals. Alexander et al. (2005) reported Q allele frequencies ranging from 45 percent to 74 percent for Columbia, Suffolk, Rambouillet, Hampshire and Targee rams. Reported frequencies of ARR haplotypes in various populations were also less than 50 percent in several studies (Isler et al., 2006; Vitezica et al., 2006; Casellas et al., 2007; Sawalha et al., 2007). Predicted means for 90-d BW were highest for the R/R genotype (41.88 kg), which was not significantly different from predicted means for Q/Q (*P = 0.13*) or Q/R (*P = 0.11*). This supports observations from several studies (Brandsma et al., 2004; Alexander et al., 2005; Vitezica et al., 2006) that selection for R/R genotypes will not compromise growth performance.

Association of PRNP Genotype and Sale Price

Genotype at the PRNP locus had a highly significant effect (*P<0.001*) on sale price (Table 1). Predicted means for R/R and Q/R were $799 (*P<0.001*) and $267 (P = 0.002) higher, respectively, than predicted means for Q/Q. The top-selling individual ($7,500) was heterozygous. The top-selling Q/Q individual ($2,750) was the tenth-highest price of those with genotype information available, indicating that qualities other than PRNP genotype were still valued by purchasers. The random-animal effect was responsible for 22 percent ± 23 of the total variance in sale price, whereas litter effects accounted for 34 percent ± 18 of the total variance. Estimates for additive and dominance effects based on the numbers in Table 1 are $400 and -$133, respectively. The corresponding allele-substitution effect for the R allele was $397.

Table 1. Genotype frequencies and predicted means for sale price and 90 day body weight (90-d BW).

Genotype	Frequency (%)	Sale Price[1] ($)	90-d BW (kg)
Q/Q	26	770 ± 76	40.29 ± 1.14
Q/R	49	1,037 ± 90	40.29 ± 0.98
R/R	25	1,569 ± 159	41.88 ± 1.15

[1] Predicted means different (*P < 0.01*)

BW and genotype interactions

The effect of 90-d BW on sale price predicted means are demonstrated in Figure 2. The regression on BW was significant when genotype was Q/Q (*P = 0.008*), or Q/R (*P = 0.028*), but not when genotype was R/R (*P = 0.41*). Predicted-sale-price means for PRNP genotype at 90-d BW of 33.7 kg and 46.2 kg are reported in Table 2. Predicted sale price was $431 more for Q/Q sheep with a 90-d BW of 46.2 kg versus a 90-d BW of 33.7 kg. The predicted means for R/R sheep when 90-d BW was in the 10th percentile (33.7 kg) was $436 more than predicted means for Q/Q sheep with 90-d BW in the 90th percentile (46.2 kg),

Table 2. Predicted sale price means when 90 day body weight is 33.7 kg and 46.2 kg.

Genotype	33.7 kg	46.2 kg
Q/Q	\$600 ± 81[a,x]	\$1,031 ± 153[a,y]
Q/R	\$892 ± 97[b,x]	\$1,224 ± 143[a,y]
R/R	\$1,467 ± 235[c]	\$1,743 ± 229[b]

[a,b,c] Column values with different superscripts are significantly different ($P < 0.05$).
[x,y] Row values with different superscripts are significantly different ($P < 0.05$)

which approached significance ($P = 0.09$). It appeared that buyers were willing to pay a premium for R/R sheep and that the sheep's performance had a relatively small impact on sale price when genotype was R/R. However, performance had a large impact on sale price for Q/Q sheep.

Implications

The results of this and other studies indicate that the scrapie-susceptibility allele is still at a high frequency, but that producers are selecting for scrapie resistance. Buyers of elite, purebred Polled Dorset stock were willing to invest in reducing scrapie susceptibility, as evidenced by sale prices for R/R sheep that were more than double those for Q/Q sheep, and a substitution effect for the R allele of $397.

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