

MODELLING THE JOINT EFFECTS OF GENOTYPE AND PROTEIN INTAKE ON RESISTANCE TO GASTROINTESTINAL PARASITE INFECTIONS IN SHEEP

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INTRODUCTION

On a global scale, gastrointestinal helminthosis is the farm animal disease with the greatest impact upon world poverty (Perry *et al.*, 2001). Anthelmintic drugs have long been the main protection against helminth parasites, but this approach is no longer sustainable due to the development of anthelmintic resistance by parasites. Therefore, alternative methods for controlling helminth parasites in sheep have been the focus of much research. These include improved nutrition and breeding for resistance to nematodes.

It has been shown in many experiments around the world that resistance of ruminant hosts to various species of nematode parasites is a heritable trait (e.g. Bishop *et al.*, 1996 ; Morris *et al.*, 2000). The heritability of the indicator trait of resistance to nematodes, faecal egg count (FEC), has usually been found to be within the range of 0.2 to 0.4. The estimates of genetic correlation between live weight gain and FEC have been found to vary considerably from strong negative (Bishop *et al.*, 1996) to slightly positive (McEwan *et al.*, 1992). In addition to the imprecision of estimation, reasons for this variation may include different breeds and parasite species, nutritional differences, etc. Furthermore, Bishop and Stear (1999) showed that the intensity of the challenge could alter the genetic correlation between productivity and resistance.

Despite conflicting results, it is thought that protein supplementation has a beneficial effect in helping the host to mount an immune response. Experimental results (Datta *et al.*, 1998) and theoretical reasoning (Coop and Kyriazakis, 1999) point to an effect of protein onto the ability of lambs to mount immune response against parasites. Therefore, improved nutrition or protein supplementation is an additional measure that can help control the impact of nematodes.

The effects of genetics and nutrition have generally been studied independently. As pointed out by Waller (1999), these measures will be probably more efficient if they are implemented in conjunction rather than separately. In order to effectively combine nutrition and genetics, many questions must be addressed. For example, is there an interaction between nutrition (protein) and genetics ? If so, will this influence genetic and phenotypic relationships between resistance and performance parameters ? Additionally, will this impact upon breeding strategies ? This paper explores, by means of computer simulation, possible interactions between genetics and nutrition (i.e. dietary protein level) on nematode resistance in lambs, and the effects of this interaction on genetic and phenotypic parameters.

MATERIALS AND METHODS

Scope of model. A model was developed which included the impact of protein nutrition level, host-parasite interactions for nematode infections and the development of immunity upon lamb growth. The model was parameterised for a population of hosts at both the genetic and phenotypic level. Output variables included predictions of growth, food and protein intake, parasite burdens and egg outputs for each individual within a genetically-structured population, enabling estimation of genetic parameters for each output variable.

Nutrition. The growth of the animals, in the absence of infection, was modelled so as to fit the tables given in Anonymous (1985) with respect to protein intake. All other nutritional requirements were assumed to be adequately met. Each day, the protein requirement of each animal was estimated based on its live weight as was actual food intake. Daily live weight gain, in the parasite free case, was then estimated as a function of the protein the animal consumed, which in turn was a function of the food intake and the protein content of the diet. The model was parameterised to simulate growth between 7 and 50 kg, with daily live weight gains between 100 and 400 g/day. Animals falling below 7 kg were considered to be culled.

Host-parasite interaction. Host parasite-interactions were based on the model of Bishop and Stear (1997). In this model acquired immunity varies between animals and increases with age. The host-parasite interaction is described by three heritable, uncorrelated traits of the host : larval establishment, fecundity of adult female parasites and parasite mortality. Moderate density dependence effects on parasite growth and fecundity were included in the model.

Parasite-induced production losses. Production losses were estimated as a function of larval challenge and worm burden, itself calculated as the product of worm number and worm size (Bishop and Stear, 1999). The worm burden component was scaled using an empirical function of protein content of the diet, such that protein-rich diets reduced this loss and protein-poor diets increased it. Actual gain (or loss) of weight was then estimated as the gain (or loss), which would have been achieved for a given amount of protein in a parasite-free situation, minus the production penalty inflicted by the parasite infection under the given nutritional regime.

Parameterisation. The model was calibrated by results of Datta *et al.* (1998). Initial mean live-weight was 10 kg and the maximum gain 220 g/day. The animals were assumed to be free of parasites in the first three months of their life. Subsequently they were artificially infected with a benchmark larval dose, so as to produce faecal egg counts similar to those seen under natural infection. The genetic parameters for the parasitological traits were those used by Bishop and Stear (1999). Live weight, food intake and maximum gain were assumed to have a heritability of 0.3. The coefficient of variation for live-weight and maximum gain was assumed to be 0.1 and for food intake 0.2. The correlation between live-weight and food intake for uninfected lambs was 0.5. The genetic correlation between live-weight at day 1 and live-weight at day 180 was assumed to be 0.9, and the phenotypic correlation for the same measurements was assumed to be 0.65. The same correlation structure was assumed for food intake.

Simulation procedure. Twenty replicates were run, each with an initial 1000 animals. The protein levels used were : 10 %, 13 %, 14 %, 16 % and 19 % crude protein in the dry matter. Lambs were dosed with larvae, administrated twice per week. All parameters are calculated daily and stochastic variation is introduced daily, in accordance with the genetic parameters and between-trait and across-time correlations. Animals with live weights outside the range 7-50 kg are removed, i.e. culled or sold. Bivariate analyses, using ASREML (Gilmour *et al.*, 1996), were performed to estimate parameters for output variables such as faecal egg counts and productivity.

RESULTS AND DISCUSSION

In table 1 mean live weight (LW) and daily dry matter food intake at day 180 are presented, for each protein level. The last column shows the average number of animals removed due to small weight. LW and food intake both increase as the dietary protein level increases. The number of animals still present on the last day also increases as the protein level increases, i.e. fewer animals fall below the threshold of 7 kg. The 10 % protein level is extreme and inadequate.

Table 1. Mean live weight (LW) and daily food intake (FI) at 180 days, and the number of lambs culled (< 7kg)

Protein Level	LW (kg)	FI (kg)	Animals below 7 kg
10 %	8.26	0.60	651
13 %	14.84	0.78	39
14 %	19.15	0.95	11
16 %	30.59	1.31	0
19 %	39.07	1.46	0

In figure 1 mean faecal egg counts (FEC) for each week are shown for the four months during which the animals were challenged. The means are shown for each protein level. Mean FEC drops as the protein level increases, since the protein is assumed to have a direct effect on the ability of the host to influence the mass and fecundity of the parasites.

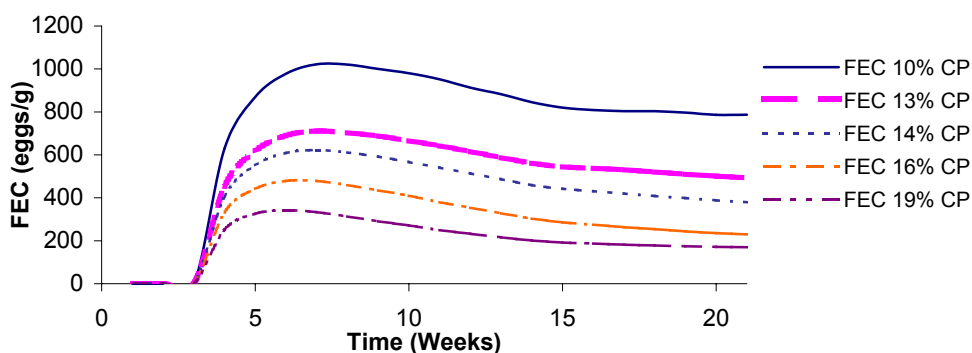


Figure 1. Mean FEC for different levels of protein over time

Genetic and phenotypic parameters, obtained from bivariate analyses of FEC and LW, are given in table 2. Results are not presented for the 10 % protein level, as many of the analyses failed to converge, possibly due to the high culling rate of lambs. The parameters estimated were in agreement with values obtained by field data analyses (Bishop *et al.*, 1996). The protein level did not significantly affect the heritabilities of LW, FEC or food intake (results not shown). However, correlations between LW and FEC were markedly affected by dietary protein level. Both the phenotypic and genetic correlations became weaker as the protein content of the diet increased. Animals on a higher plain of nutrition had more protein available for overcoming the effects of parasitism, which resulted in the weaker correlations.

Table 2. Effect of dietary protein content on the estimated heritabilities for, and genetic (rg) and phenotypic (rp) correlations between, FEC and LW (with standard errors)

Protein Level	FEC h ²	LW h ²	r _p	r _g
13 % CP	0.35 (0.02)	0.21 (0.02)	-0.15 (0.01)	-0.22 (0.05)
14 % CP	0.32 (0.02)	0.19 (0.02)	-0.15 (0.01)	-0.28 (0.05)
16 % CP	0.35 (0.02)	0.20 (0.02)	-0.07 (0.01)	-0.07 (0.06)
19 % CP	0.34 (0.02)	0.22 (0.02)	-0.02 (0.01)	-0.02 (0.05)

In conclusion, this study indicates that differences in dietary protein levels or protein supplementation may result in a genotype by nutrition interaction such that the correlation between resistance and performance is dependent upon the level of nutrition. This may partly explain differences seen between genetic parameters from different experiments in which nutritional levels may well have varied. Additionally, different breeds can also have different protein needs, which will result in different estimated parameters, even if put on the same feeding regimen. A next step is to utilise these results to design control programmes for nematode infections which incorporate selection along with appropriate protein nutrition.

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