VARIATION IN THE SULPHUR CONTENT OF WOOL OF MERINO SHEEP ASSOCIATED WITH GENETIC DIFFERENCES IN WOOL-PRODUCING CAPACITY*

By L. R. PIPER† and C. H. S. DOLLING†

The sulphur content of wool may be influenced by a number of factors. Copper deficiency has been shown to reduce sulphur content (Marston 1946), while the administration of sulphur-containing amino acids or casein directly into the abomasum has been shown to increase substantially both the sulphur content of wool and the rate of wool growth (Reis and Schinckel 1961, 1963, 1964). Variation in the nutritional status of both pen-fed (Reis 1965) and grazing (Reis and Williams 1965) sheep, associated with variation in either the amount or the composition of the diet, has also been shown to influence sulphur content; wool growth and sulphur content have both increased as nutrition has been improved, and vice versa. Variation in the sulphur content of wool from grazing sheep has also been reported by Ross (1961, 1964) who suggested that there was an inverse relationship between rate of wool growth and its sulphur content. The sheep observed by Ross were Romney ewes and Reis and Williams (1965) have cast some doubt on the relationship suggested by Ross on the grounds that the seasonal variation in wool growth may have been affected by factors other than nutrition.

Most workers have also reported considerable variation between animals in the sulphur content of wool. In the reports of Reis (1965), Reis and Williams (1965), and Gillespie and Reis (1966), there is an indication that some of the between-animal variation may be associated with differences in wool-producing capacity, higher wool producers tending to grow wool of a lower sulphur content. In these experiments, however, numbers of animals were small, and the differences in wool-producing capacity are phenotypic and would have been partly genetic and partly environmental in origin.

To determine with greater certainty the effect of genetic differences in wool-producing capacity on wool sulphur content we have compared the sulphur content of the wool of 20 Merino ewes, 10 from each of two selection groups. The ewes were born in 1963 on the CSIRO National Field Station, "Gilruth Plains", Cunnamulla, Qld., in an experiment discussed by Turner (1959). In one group selection is solely for high and in the other solely for low clean wool weight per head at *c.* 16 months of age. The experiment commenced in 1954, and in February 1965 the mean clean wool weight per head for ewes born in 1963 in the high group was 64% above the corresponding mean of the low group.

* Manuscript received April 26, 1966.

† Division of Animal Genetics, CSIRO, "Gilruth Plains", Cunnamulla, Qld.

Wool samples for sulphur analysis were taken in June, 1965, when the ewes were *c.* 20 months old and were carrying 4 months' wool, grown while they had been grazing together on natural pasture. In the correlations presented, wool sulphur content was related to the weight of clean wool obtained when the ewes were shorn at *c.* 16 months of age. This age difference between observations should not affect the correlations unduly, however, if the high estimate of repeatability for wool weight obtained by Young, Turner, and Dolling (1960) holds for the sheep observed here.

TABLE 1

MEANS, VARIANCES, AND RANGES FOR SULPHUR CONTENT OF WOOL SAMPLES TAKEN FROM EWES AT *c.* 20 MONTHS OF AGE, AND CLEAN WOOL WEIGHT AND BODY WEIGHT OF THESE EWES AT *c.* 16 MONTHS OF AGE

Results for 10 ewes from each of two groups under selection for high and low clean wool weight

Character	High Clean Wool Weight Group			Low Clean Wool Weight Group		
	Mean	Variance	Range	Mean	Variance	Range
Sulphur content* (%)	2·98	0·0091	2·84–3·14	3·45	0·0051	3·34–3·58
Clean wool weight (lb)	5·24 (0·7170)†	0·3004 (0·002258)†	4·1 –5·9	3·01 (0·4767)†	0·0766 (0·001638)†	2·6 –3·4
Body weight (lb)	58·10	58·9889	46 –68	55·40	31·0444	46 –68

* Of wool from sheep grazing very poor drought-affected natural pasture.

† Means and variances of transformed data.

A wool sample of *c.* 70–100 g was taken from the right midside of each fleece. This was divided into *c.* eight parts, from each of which two small staples were drawn. Two subsamples, each of *c.* 100 mg, were then made up by bulking together one staple from each pair. An estimate of sulphur content was made on each subsample, duplicate estimates for each ewe thus being available.

The subsamples were cleaned by washing three times in a hydrocarbon solvent (Shell X4), twice in a wetting agent (Teepol), and by rinsing with distilled water and finally with ethanol. They were then dried at 105°C for 16–20 hr and the clean dry wool (now *c.* 70 mg) was weighed to the nearest 0·0001 g prior to analysis. Sulphur (expressed as % in clean dry wool) was measured as described by Reis and Schinckel (1963). The difference between duplicate estimates of sulphur content varied from 0·01 to 0·09%, the mean being 0·04%.

The mean values for sulphur content of wool for each group of ewes at *c.* 20 months of age and clean wool weight and body weight at *c.* 16 months of age are shown in Table 1, together with the variances and the range of values for each character. The low group had a higher mean sulphur content of wool than the high group and there was no overlap between groups in either sulphur content or clean wool production. Taking the low group values as 100 in each case, the high group values are 86 for sulphur content, 174 for clean wool weight, and 105 for body weight. The differences between the means were significant ($P < 0 \cdot 001$) for sulphur content and clean wool weight ($t_{18} = 12 \cdot 368$ and $12 \cdot 198$ respectively) but not for body weight ($t_{18} = 0 \cdot 90$). In the case of sulphur content the mean of the duplicate estimates for each ewe was used in the t-test and in the case of clean wool weight the original values were converted to logarithms (to base 10) before analysis because of a significant difference between the variances in the original data.

The difference in sulphur content of wool shown here between groups is genetic in origin. Other workers (Reis 1965; Reis and Williams 1965; Gillespie and Reis 1966) have reported differences between high and low producers within flocks, but the differences reported by them are phenotypic and the relative importance of the genetic and environmental components cannot be estimated. Our work has been reported as it clearly demonstrates variation in wool sulphur content associated with *genetic* variation in wool-producing capacity. An estimate of the strength of the association is not possible from these data, but examination of the group means for wool production and sulphur content does suggest that it will be negative in sign.

The within-group or phenotypic correlation between clean wool weight and sulphur content was calculated for each group. The correlations were $-0 \cdot 6867$ ($0 \cdot 05 > P > 0 \cdot 02$) for the low group and $+0 \cdot 2832$ ($P > 0 \cdot 10$) for the high group. They were significantly different from each other when tested by means of a z-transformation (Fisher 1954). The within-group relationship for the low group is similar to that observed by other workers (Reis 1965; Reis and Williams 1965; Gillespie and Reis 1966), but this is not so for the high group.

Alternative explanations of this difference may be forthcoming when further work has been completed, but for the present that given below seems valid and is not inconsistent with the available literature. Reis and Williams (1965) found that both wool sulphur and rate of wool growth were closely related to the amount of edible forage available. However, they observed that, towards the end of a period of continuing low pasture availability, the otherwise consistent relationship between sulphur content and rate of wool growth did not hold and that sulphur content remained almost unchanged while wool growth continued to fall. This observation was consistent with the finding of Reis (unpublished data, referred to in Reis and Williams 1965) that on restricted diets containing very little sulphur the wool growth rates fell to very low levels (*c.* $0 \cdot 1$ mg/cm^2/day) while the sulphur content could not be forced below a certain "minimum" value.

During the growth period of the fleeces from which samples were taken for the sulphur analyses presented here the animals were grazing on very poor drought-affected natural forage. It was not surprising, then, that the sulphur estimates were low for all sheep (cf. Reis and Williams 1965). Under conditions such as these of low availability of edible forage Reis and Williams (1965) observed that the sulphur content of wool of high producers fell more than that of low producers. Thus the high group here could have been approaching "minimum" sulphur values, both because of intrinsically low wool sulphur contents and because of the poor environmental conditions, and the variation in sulphur content may have been greatly reduced relative to the variation in wool production. Under the same conditions the low group could have been well above "minimum" sulphur values and have been exhibiting normal variation in sulphur relative to that of wool production. A difference such as this could lead to a different relationship between wool-producing capacity and sulphur content within each group and may have been the cause of the difference observed here. On this hypothesis, one would predict that the relationship between wool-producing capacity and sulphur content would be of the same sign in each group if the sheep were grazing pasture much superior to that offered here.

Dolling and Moore (1960) have compared the efficiency with which ewes from these two groups converted food to wool. They found that a large part of the wool-production difference observed in pens was due to a difference in efficiency of conversion of food to wool. The ewes used by them were born at an early stage of the experiment but it would not be unreasonable to assume that a large part of the wool-production difference between the 1963 drop ewes of the two groups is also attributable to a difference in efficiency of conversion. It is suggested that some portion of this efficiency difference is associated with a difference between groups in efficiency of utilization of ingested sulphur at the follicle level, the mechanism of which may be the production of different proportions of the high and low sulphur proteins of which wool keratin is composed. Some support for this contention is found in the work of Gillespie and Reis (1966) in which one high- and one low-producing sheep, fed similarly, produced wools of different sulphur contents (3·00 and 3·65% respectively) and with different proportions of the high sulphur protein (20 and 25% respectively).

We wish to thank Mr. P. J. Reis for his guidance and assistance in the determination of the sulphur contents of the wools.

References

Dolling, C. H. S., and Moore, R. W. (1960).—*Aust. J. Agric. Res.* **11**: 836–44.

Fisher, R. A. (1954).—"Statistical Methods for Research Workers." 12th Ed. p. 203. (Oliver and Boyd: London and Edinburgh.)

Gillespie, J. M., and Reis, P. J. (1966).—*Biochem. J.* **98**: 669–77.

Marston, H. R. (1946).—"In Fibrous Proteins: A Symposium". p. 207. (Society of Dyers and Colourists: Leeds.)

Reis, P. J. (1965).—*Aust. J. Biol. Sci.* **18**: 671–87.

Reis, P. J., and Schinckel, P. G. (1961).—*Aust. J. Agric. Res.* **12**: 335–52.

Reis, P. J., and Schinckel, P. G. (1963).—*Aust. J. Biol. Sci.* **16**: 218–30.

Reis, P. J., and Schinckel, P. G. (1964).—*Aust. J. Biol. Sci.* **17**: 532–47.

Reis, P. J., and Williams, O. B. (1965).—*Aust. J. Agric. Res.* **16**: 1011–20.

Ross, D. A. (1961).—*Proc. N.Z. Soc. Anim. Prod.* **21**: 153–65.

Ross, D. A. (1964).—*N.Z. J. Agric. Res.* **7**: 663–5.

Turner, Helen Newton (1959).—*Aust. J. Agric. Res.* **10**: 565–80.

Young, S. S. Y., Turner, Helen Newton, and Dolling, C. H. S. (1960).—*Aust. J. Agric. Res.* **11**: 257–75.