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Wool yellowing and pH within Merino and Romney fleeces

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ABSTRACT

Fleece samples were taken from the back, side and belly of three adult ewes in one Merino flock and three adult ewes in one Romney flock in each of six regions of New Zealand (Waikato, Manawatu, Wairarapa, Marlborough, Canterbury, Otago). Each fleece was 12 months growth. These samples were used to compare factors associated with wool yellowing as measured by tristimulus (Y-Z) values. Neither the region of New Zealand where the sheep grazed nor the measured dimensional fleece characteristics, were related to fleece yellowing. The pH of an aqueous extract of greasy wool was strongly related (R^2 = 0.93) to tristimulus (Y-Z) (base yellow) at shearing but less strongly related (R^2 = 0.70) to tristimulus (Y-Z) after the sample had been incubated at 40°C and 100% RH for 6 d. Merino samples had a lower tristimulus (Y-Z), both before and after incubation, at a particular pH than Romney samples. Back wool did not increase in yellowness as much during incubation as side or belly wool possibly on account of photo-oxidation following prolonged exposure to sunlight. These data indicate a close relationship between pH of a water soluble component of greasy wool and the extent of wool yellowing that was influenced by sheep breed and body site.

Keywords: wool; Merino; Romney; yellowing; body site; pH.

INTRODUCTION

Unscourable yellow discolourations develop in wool while the wool is growing on the sheep, during storage and during processing (Aliaga *et al*., 1996). Although the origins and chemistry of the discolourations are poorly understood (Simpson (1999), some factors associated with wool yellowing in a growing fleece are the presence of suint (Winder *et al*., 1998a), aided by moisture, warmth and impaired ventilation (Hoare & Stewart, 1971). Breeds differ in their predisposition to fleece yellowing (Reid & Botica, 1995) as do individual sheep in a flock (Wilkinson, 1982), indicating a genetic basis for the propensity of wool to yellow (Benavides *et al*. 1995).

Positive correlations have been reported between the pH of aqueous extracts of wool and the extent of wool yellowing for both greasy (Aitken *et al*., 1994; Siqueira & Fernandes, 1994; Winder *et al*., 1998b) and moist scoured (Simpson, 1999) wool.

Studies on aspects of the biology of wool yellowing in individual fleeces have mainly been undertaken using a mid-side sample, which is accepted as being the most representative site of the fleece for sampling sheep for a range of fleece measurements (Turner, 1956) thereby ignoring the large ventro-dorso gradient in yellowing present within individual fleeces (Bigham *et al*., 1984).

This paper is a report of a study that compared factors associated with wool yellowing within the fleeces of Merino and Romney ewes grazing on several farms throughout New Zealand that experience different climatic conditions. The study was undertaken as part of a larger programme examining the biological and environmental factors involved in wool yellowing.

MATERIALS AND METHODS

Sheep

One "typical" Merino and one "typical" Romney flock, each with a wide range of fleece yellowing, were selected by WoolPro Sheep Production Officers within each of six geographical regions of New Zealand (Waikato, Manawatu, Wairarapa, Marlborough, Canterbury and Otago). Five young adult ewes with a 12-month fleece, were identified at random within each of these flocks immediately before shearing. As each sheep was shorn, the unskirted fleece was rolled with its associated belly and stored in an identified black plastic bag that was kept cool during transportation to the laboratory and later storage. All fleeces were weighed and three fleeces from within each flock that were similar in fleece weight, staple length and fleece type, but with a wide range of subjectively assessed yellowness, were selected for detailed measurement. Each selected fleece (6 regions x 2 breeds x 3 sheep) was unrolled and an approximately 350 g sample taken from the back, right side and belly areas of the body. The shape of the sampled site for the back and side samples was a long rectangle stretching the length of the fleece, excluding the neck in the case of the back sample. The complete belly, as removed by the shearer, was used.

Wool measurements

Mean staple length of each fleece sample was measured by ruler as the mean of three staples drawn at random from each sample. The total number of crimps along each staple was counted and the mean crimp frequency calculated. Each fleece sample was blended by passing it through a mechanised revolving drum opener and the carded batt cut to simulate a core-bored sample (internal diameter approximately 18 mm diameter) with a press and cutting grid. The snippets were blended in a stream of compressed air within a large plastic "bubble blender" (Burling-Claridge, 1994). Random sub-samples of each blended snippet sample were used for all subsequent wool measurement procedures.

Mean fibre diameter and fibre diameter variation, and fibre curvature, of scoured mini-cored snippets of each blended sample were measured simultaneously with an

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OFDA100 instrument.

The pH of an aqueous extract of a sub-sample of each blended greasy wool sample was measured by the IWTO Standard method, IWTO-2-96. A second sub-sample of each blended greasy wool sample was subjected to a modification of Aliaga *et al.*'s (1996) challenge test where each greasy sub-sample was moistened with deionised rather than tap water. Subsequently the sub-samples were held at 40°C and 100% relative humidity for 6 d in an incubator and left to dry at room temperature. Wool colour before (base yellow) and after (challenge yellow) incubation was measured according to the New Zealand Standard method (NZS8707:1984) using reference wool for calibration, illuminant C and a 2° observer angle. Equations to convert these data to the alternative system using a tile for calibration, illuminant D65 and a 10° observer angle, currently being introduced into the New Zealand wool industry, are given by Reid & Urquhart (2003).

Statistical analysis

Individual measurements were analysed by analyses of variance (GENSTAT) (Lawes Agricultural Trust, 1993) fitting effects of geographical region of the source farm, breed of sheep and body sampling site. Curvilinear responses were analysed by Bayesian smoothing (Upsdell, 1994). The method used involved fitting mixed models with structured covariance matrices and plotting predictions for the separate parts of the model. Models differing in complexity were fitted and their fit compared by the standard deviation of the error terms and whether the curves were significantly different at the 5% level, as indicated by their 83% confidence bands not overlapping. Since there was only one farm of each breed sampled in each region, the region x breed interaction is totally confounded with the farm effect and has been interpreted as a farm effect. Separate sheep and farm effects were included in each model to allow for differences in sheep and farms which, together with the residual variance, were deemed the error terms. An adjusted R^2 value, the proportion of variation in wool yellowing explained by the measured characteristics, was computed as 1 – (sum of variances of error terms) / (residual variance fitting only a constant).

RESULTS

Least-square means and standard errors of differences for the fibre dimensional measurements, tristimulus (Y-Z) values of the measured wool samples and pH of the aqueous extract are given in Table 1. Only the main effects are presented as there were no significant interactions between breed, regions of New Zealand and body sampling site for any of the measured characteristics.

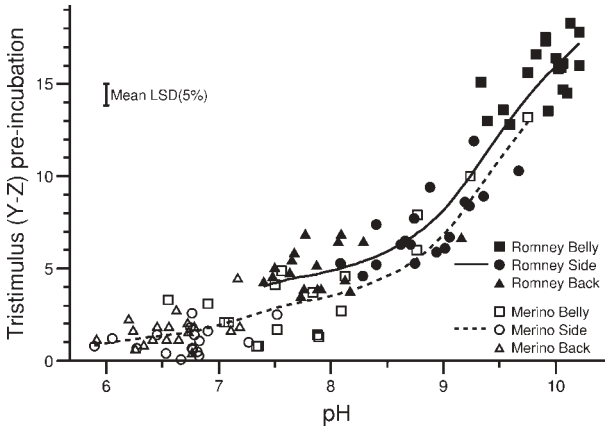
There were highly significant differences between the two breeds for all measurements with the Merino samples being shorter, finer, having more crimps and, therefore, a higher fibre curvature, less yellowness before and after incubation and a lower pH of the aqueous extract than the Romney samples. Fibre curvature, which reflects the openness of the fleece and hence its rate of drying following wetting, was the only characteristic with a significant regional effect. This probably reflected chance variation between flocks rather than a meaningful regional effect.

While there were no detectable differences between crimp frequency and mean fibre diameter between body sampling sites, there were highly significant differences for each of the other measured characteristics. Wool on the belly was shorter and had fewer total crimps than wool on the side with the wool on the back being intermediate for these two characteristics. The belly wool also had a higher fibre curvature than the side and back wool, which were not significantly different. Tristimulus (Y-Z) and pH of the aqueous extract progressively increased over the

TABLE 1: Least-square means and standard error of difference (SED) for dimensional measurements, pH, pre-incubation tristimulus (Y-Z) (base yellow) and post-incubation tristimulus (Y-Z) of 108 wool samples from 3 body sites of 2 breeds of sheep on farms in 6 regions of New Zealand.

Effect	Staple length (mm)	Total crimps	Mean crimp frequency (crimps/cm)	Mean fibre diameter (μm)	Mean fibre curvature (°/mm)	Pre-incubation		Post incubation
						pH	Tristimulus (Y-Z)	Tristimulus (Y-Z)
Breed								
Merino	77	38	5.0	18.4	108	7.1	2.4	9.5
Romney	129	14	1.1	37.5	38	8.9	9.3	14.7
SED	3	2	0.2	1.0	2	0.2	0.8	0.6
Region								
Waikato	104	26	2.9	29.2	69	8.1	6.5	13.0
Manawatu	105	26	2.9	28.6	71	8.0	6.0	11.2
Wairarapa	100	28	3.3	27.3	78	7.8	5.9	12.1
Marlborough	104	23	2.7	28.7	66	7.8	5.5	12.2
Canterbury	102	26	3.1	26.9	80	8.1	5.8	12.6
Otago	103	28	3.3	27.2	74	8.1	5.4	11.5
SED	5	3	0.3	1.7	3	0.4	1.3	1.0
Body site								
Back	108	26	3.0	27.9	72	7.2	3.4	10.5
Midside	117	30	3.0	28.0	71	7.8	4.3	12.0
Belly	84	23	3.1	28.1	77	8.9	9.8	13.8
SED	2	1	0.1	0.3	1	0.1	0.3	0.2
Breed	***	***	***	***	***	***	***	***
Region	NS	NS	NS	NS	*	NS	NS	NS
Body site	***	***	NS	NS	***	***	***	***

FIGURE 1: Relationship between tristimulus (Y-Z) (base yellow) of 108 wool samples from two breeds sampled at three body sites and pH of an aqueous extract of the same samples in a greasy state.



body from the back to the belly.

After adjusting the tristimulus (Y-Z) values before and after incubation for the effects of breed and body site, the slope of the relationship of each tristimulus (Y-Z) value with each of the measured dimensional fibre characteristics listed in Table 1, was not significantly different from zero. There were however significant curvilinear relationships between both tristimulus (Y-Z) before incubation (base yellow) (Figure 1) and tristimulus (Y-Z) after incubation (Figure 2) with the pH of the aqueous extract. The best fits were a curve for pH with an additive constant for breed. This accounted for 93% of the variance for tristimulus (Y-Z) before incubation (base yellow) (Figure 1) and 79% of the variance for tristimulus (Y-Z) after incubation (Figure 2). Adding terms involving body site did not improve the fit of either model nor did allowing different curve shapes for the pH of each breed. In both cases, the curve for the Romney sheep was significantly different to the curve for the Merino sheep and the Romney samples were more yellow at any given pH than the Merino samples.

There was also a curvilinear relationship between yellowness before, and yellowness after, incubation

FIGURE 2: Relationship between tristimulus (Y-Z) of 108 wool samples from two breeds sampled at three body sites after being incubated and pH of an aqueous extract of the same samples in a greasy state prior to their being incubated.

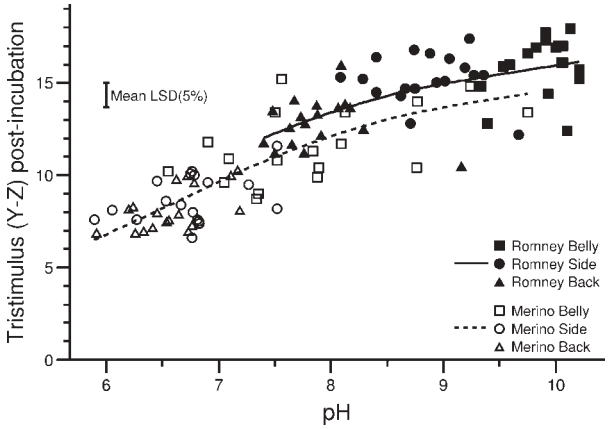
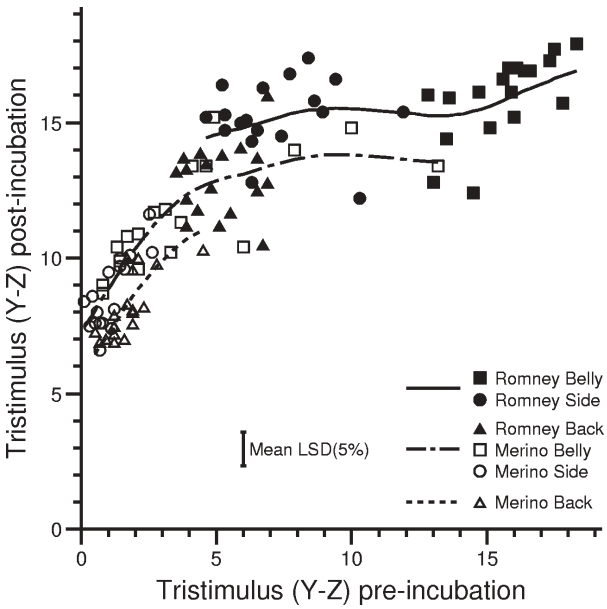


FIGURE 3: Relationship between tristimulus (Y-Z) of 108 wool samples from two breeds sampled at three body sites after being incubated and tristimulus (Y-Z) (base yellow) before being incubated.



(Figure 3). The yellower the samples were before incubation, the less the increase in yellowness during incubation. The best fit for this relationship was a curve for yellowing before incubation and additive constants for each breed and body site. This accounted for 87% of the variance (Figure 3). The shape of the curves for the side and belly were not significantly different, whilst that for the back was significantly ($P<0.05$) lower than the curves for the side and belly. The curves for the Merino were also significantly ($P<0.05$) lower than the curves for the Romney. The curve for the Romney back samples was not significantly different to the curve for the Merino side and belly samples. For ease of presentation (Figure 3), the three curves for Romney back, Merino side and Merino belly are plotted as one, as are the curves for Romney side and Romney belly.

DISCUSSION

The observed trends for the dimensional and tristimulus data align with previous reports for Merino and Romney sheep (summarised by Pearson *et al*., 1999) and for samples taken from different body sampling sites (Bigham *et al*., 1984).

These results further confirm that wool yellowing is associated with the pH of an aqueous extract of greasy wool and that the agent concerned is readily transferred to the lower regions of the fleece during growth, presumably by wetting of the fleece during rain. The different curvilinear pattern of wool yellowing during an incubation challenge between greasy side and belly samples , and greasy back samples (Figure 3), suggests that prolonged exposure of back wool to sunlight may influence the biochemical pathway associated with wool yellowing in greasy wool.

Wool “yolk”, the “greasy” film surrounding growing wool fibres, consists of two principal fractions; a water

soluble suint fraction that is thought to be secreted into the growing fleece by the sudoriferous or sweat glands situated in the skin at the base of the primary wool follicles, and a water insoluble wax fraction that is secreted by sebaceous glands that are associated with all wool follicles (Ryder & Stephenson, 1968). While fleece yellowing is associated with the presence of suint, wool wax is considered to act as a protection against fleece yellowing (Hoare &Stewart, 1971). Both Merino and Romney sheep have a similar density of primary follicles within their skin, and hence a similar density of sudoriferous glands (Ryder & Stephenson, 1968), with a similar amount of suint in their fleeces (Henderson, 1965). Merino sheep, on the other hand, have approximately twice the density of total follicles, and hence twice the density of sebaceous glands, compared with Romney sheep (Ryder & Stephenson, 1968), potentially suggesting why Merino fleeces have a significantly higher wax content than Romney fleeces (Henderson, 1965). Despite the potential difference in the amount of wax in the fleeces of these two breeds, the magnitude of the difference in yellowness between Merino and Romney fleeces under similar pH conditions was relatively small highlighting the importance of an agent associated with suint on yellowing and suggesting the presence of increasing amounts of wax in the fleece may be of decreasing importance in protecting the fleece against yellowing.

In this study, consistency in the relationship between pH of the aqueous extract of the greasy sample and the yellowness of the sample was more pronounced than in some earlier reports (Aitken *et al*., 1994; Siqueira & Fernandes, 1994; Winder *et al*., 1998b), largely on account of the wider range in yellowness within the current sample set. The weaker relationship between the pH of the aqueous extract measured before incubation and yellowness of the samples after they had been incubated for 6 d, suggests that the pH of the immediate environment of the wool fibre may change during an incubation challenge. This aspect requires further evaluation.

High pH within a greasy fleece is thought to derive from a breakdown in the carbonic acid/bicarbonate buffer that exists in suint (Simpson, 1999) in association with the oxidation of any unstable organic acids that may be present (Farnsworth, 1956). Bacteria are also known to play a role in wool yellowing under moist conditions (Winder *et al*., 1998b). Their effect may be secondary to pH of the water-soluble fraction surrounding greasy wool fibres or they may produce compounds contributing to the high pH levels associated with discolouration. Although Winder *et al*. (1998b) showed that wool can develop equivalent yellow discolourations during incubation in the absence of bacteria, they did not measure pH conditions in their small number of irradiated samples.

These results indicate that while the pH of the immediate environment surrounding wool fibres in the greasy state is closely related to wool yellowing, it is still unclear whether high pH has a direct causal effect on fleece yellowing.

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REFERENCES

Aitken, F.J.; Cottle, D.J.; Reid, T.C.; Wilkinson, B.R. 1994: Mineral and amino acid composition of wool from New Zealand merino sheep differing in susceptibility to yellowing. *Australian journal of agricultural research 45*: 391-401

Aliaga, J.L.; Sanderson, R.H.; Maher, A.P.; Reid, T.C. 1996: Optimising of the challenge test for the susceptibility of wool to yellow discolouration. *Proceedings of the New Zealand Society of Animal Production 56*: 319-323

Benavides, M.V.; Young, M.Y.; Beatson, P.R.; Maher, A.P.; Reid, T.C. 1995: Wool yellowing susceptibility: Heritability, genetic and phenotypic correlations with productive traits in Australian Merino, Corriedale and New Zealand Romney sheep. *Proceedings of the New Zealand Society of Animal Production 55*: 45

Bigham, M.L.; Sumner, R.M.W.; Cox, N.R. 1984: Sources of variation and experimental design criteria for wool colour measurements applied to Romney, Coopworth, and Perendale flocks. *New Zealand journal of experimental agriculture 12*: 231-236

Burling-Claridge, G.R. 1994: Background to the development of the core bulk test. WRONZ Report No. R208. Wool Research Organisation of New Zealand. pp93

Farnsworth, A.J. 1956: Investigations on suint. *Australian journal of applied science. 7*: 233-241

Henderson, A.E. 1965: *Wool and woolclassing*. A.H. and A.W.Reed, Wellington. pp 66-71

Hoare, J.L.; Stewart, R.G. 1971: Some aspects of suint composition and yellow discolouration in New Zealand wools. *Journal of the Textile Institute 62*: 455-464

IWTO-2-96. Method for the determination of the pH value of a water extract of wool

Lawes Agricultural Trust, 1993: *GENSTAT 5. Release 3. Reference manual*. Rothamsted Experiment Station, Harpenden, Clarendon Press, Oxford. pp796

NZS8707:1984: Method for the measurement of colour in wool

Pearson, A.J.; Ashby, M.G.; Nixon, A.J.; Sumner, R.M.W. 1999: Seasonal wool growth patterns and the follicle and fibre characteristics of New Zealand feral sheep. *Proceedings of the New Zealand Society of Animal Production 59*: 34-38

Reid, T.C.; Botica, K.J. 1995: Relationship between wool colour and fibre diameter in four breeds of sheep. *Proceedings of the New Zealand Society of Animal Production 55*: 50-53

Reid, T.C.; Urquhart, R.A. 2003: Effect on wool yellowing of dipping sheep with zinc. *Proceedings of the New Zealand Society of Animal Production 63*: 164-168

Ryder, M.L.; Stephenson, S.K. 1968: *Wool growth*. Academic Press, London. pp 805

Simpson, W.S. 1999: Physics and chemistry of wool yellowing. WRONZ Report R217. Wool Research Organisation of New Zealand. pp 36

Siqueira, E.R.; Fernandes, S. 1994: Grease content, water extract, pH and weathering effects in wool from Australian Merino, Polwarth, Corriedale, Romney and Ile de France breeds in southeast Brazil. *Fine fibre news 3*: 14-16

Turner, H.N. 1956: Measurement as an aid to selection in breeding sheep for wool production. *Animal breeding abstracts 24*: 87-118

Upsdell, M.P. 1994: Bayesian smoothers as an extension of nonlinear regression. *The New Zealand Statistician 29(2)*:66-81

Wilkinson, B.R. 1982: Yellowing in wool. *Wool 7 (4)*: 9-16

Winder, L.M.; Rea, A.; Scobie, D.R.; Bray, A.R. 1998a: Unravelling the causes of wool yellowing. Part I: Involvement of a water soluble component. *Proceedings of the New Zealand Society of Animal Production 58*: 274-276

Winder, L.M.; Rea, A.; Baronian, K.; Webber, J.; Muller, B. 1998b: Unravelling the causes of wool yellowing. Part II: Involvement of bacteria. *Proceedings of the New Zealand Society of Animal Production 58*: 277-280