Can dipping sheep with zinc sulphate reduce wool yellowing?

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ABSTRACT

On each of four farms, groups of ewes were either not dipped, dipped once or dipped twice with zinc sulphate solution (20 g/l). Base and challenge yellowness were determined on core wool samples collected at shearing. Dipping with zinc sulphate increased the zinc concentration of wool at shearing from 154 (range 77-321) to 421 (range 116-1140) (dipped once) or 806 (range 143-1920) mg/kg (dipped twice). Zinc sulphate dipping had no effect on the base yellowness of wool on three farms, but significantly reduced wool base yellowness on the fourth farm (Tristimulus (Y-Z) = 9.0 vs. 7.8 vs. 8.5 for control, dipped once and dipped twice, respectively) ($P<0.01$). In the laboratory, wool samples from all farms were significantly less yellow after challenge when sprayed before challenge with zinc sulphate solution than when sprayed with water (9.9 vs. 10.9; 7.1 vs. 10.0; 8.3 vs. 10.6; 11.3 vs. 13.1) ($P<0.001$). There was a significant relationship (R^2 = 83.4%, $P<0.001$) between the changes in zinc concentration resulting from zinc dipping and the changes in yellowness of the wool with challenge. These results indicate that dipping sheep with zinc may reduce discoloration of greasy wool at shearing under environmental conditions in which yellowing is maximised.

Keywords: Crossbred wool; yellowing; zinc sulphate; challenge test; propensity to yellow.

INTRODUCTION

Unscourable yellow discoloration of wool is an important processing attribute that has a strong seasonal component. Yellow discoloration of wool restricts the colour to which it can be dyed, affecting its end uses and, hence, reducing returns to wool growers. Wool yellowing is a complex process involving warmth and humidity (Wilkinson, 1982) and probably the bacteria present in the fleece (Cottle *et al.*, 1992; Gochel *et al.*, 1992). Differences between sheep in propensity of their wool to yellow have been associated with differences in suint production (Aitken *et al.*, 1994).

Zinc compounds are known to be effective in reducing bacterial growth and in assisting in the maintenance of skin health. Anecdotal information suggests some farmers regularly add zinc sulphate to the dip solution used on sheep in the belief that it reduces the yellow discoloration of their clip at the subsequent shearing.

The aim of the trial described in this paper was to determine if dipping sheep with zinc sulphate in early summer could be useful in reducing wool yellowing under a range of commercial conditions. The trial also examined the effect of spraying wool with zinc solution in the laboratory on the propensity of the wool to yellow under controlled environmental conditions (Aliaga *et al.*, 1996; Wilkinson, 1982).

MATERIALS AND METHODS

On-farm

On each of four farms located between Gore in Southland and Waingaro in Western Waikato, the flocks of available ewes were divided into three groups at random. The aim was that each group would consist of sufficient ewes to provide at least two bales of wool at shearing. Treatments applied were:

Group 1. Control – no treatment.

Group 2. Dipped once with 20 g/l zinc sulphate solution in late spring/early summer.

Group 3. Dipped twice with 20 g/l zinc sulphate solution, once in late spring/early summer and again in mid-summer.

Farms 1 and 3 used jetting or spray races to apply the dip treatments, Farms 2 and 4 used shower dips.

The locations of the four farms, the sheep breeds used, shearing dates and treatment application dates are given in Table 1. Farms 1 and 2 were shearing at six-monthly intervals, while Farms 3 and 4 were shearing at 12 monthly intervals.

On Farm 1, the whole mob of approximately 900 rising two-tooth ewes was divided into three groups for the trial. On the other three farms mixed age ewes were used. On Farm 2 only 20 sheep were kept as controls, with 200 and 146 in groups two and three, respectively. On Farm 3 there were 80-100 ewes in each of the three groups and on Farm 4 two groups of 100 ewes were selected at random from a mob of 600 ewes for the two zinc dipping treatments with the remaining 400 ewes acting as the control group. See Table 3 for the number of sheep shorn in each treatment group on each farm.

Base yellowness was measured (NZS8707:1984) on core samples taken after shearing from the main fleece lines of wool from each group of sheep. On Farms 1 and

TABLE 1: Details of farm location, sheep breed and timing of shearing and dipping on the four farms used in this trial.

Farm	Location	Sheep breed	Shearing 2001	Zinc dipping First	Zinc dipping Second	Shearing 2002
1.	Waingaro (Waikato)	Romney × Finn × Poll Dorset	July	15/11/01	21/12/01	31/1/02
2.	Waitomo (King Country)	Perendale	Sept	11/1/02	15/2/02	5/3/02
3.	Te Puke (Bay of Plenty)	East Friesian × Coopworth × Border × Dorset	June	14/1/02	6/3/02	10/7/02
4.	Gore (Southland)	Border Romney	March	20/12/01	7/2/02	6/4/02

3 the bales of shorn wool from each treatment group were core sampled to provide eight separate samples from each treatment group. On these two farms, core samples of the oddments lines from each treatment group were also collected and analysed for base yellowness. On Farm 2, one core sample was obtained from the fleeces from the 20 control ewes. The bales of wool from the other two groups were core sampled as above. On Farm 4, as only one core sample of fleece wool was taken from each group no statistical analysis of the yellowness data on this farm was possible. These samples were sent to a test-house for testing. The three keeper samples from this farm were obtained from the test-house to allow the laboratory challenges to be carried out.

The international method used for measuring wool colour is currently being changed to IWTO-56-02. Details of this change and the equations to interconvert measurements between the new and current methods of measurement are given in the Appendix.

Samples of full-length wool were collected from the mid-side of 20 randomly selected ewes from each treatment group before the initial treatment and again before shearing. Mean staple length was calculated as the mean of three staples drawn at random from each sample and measured by ruler. Within each farm these samples were then bulked according to each treatment group. These bulked samples were blended in a bubble blender and conditioned overnight. A weighed sub-sample (~0.5 g) of each was then digested in a 1:5 mixture of perchloric:nitric acids and the zinc concentration of the digest determined using a flame atomic absorption spectrophotometer.

The trial protocol was approved by Lincoln AgResearch Animal Ethics Committee (Application 01/09).

In-vitro

The propensity of the main fleece lines from each treatment group within each farm to yellow was determined on sub-samples taken at random from blended core samples by incubating at 40°C, 100% RH for six days (Aliaga *et al.*, 1996; Reid, 1993). The effect of zinc sulphate solution on the propensity to yellow was determined by spraying with either water (two sub-samples) or a 50 g/l solution of $ZnSO_4$ (two sub-samples) before incubation.

Statistical analysis

The data on wool yellowness before and after incubation were analysed by analysis of variance using GenStat (Lawes Agricultural Trust, 2000), with each farm being analysed separately. Where data for yellowness of oddments lines were available, differences between their yellowness and that of the main line were removed as a block effect. On each farm, where the overall analysis indicated a significant difference, means for the treatment groups were compared using least significant differences.

The effects of zinc dipping on the concentrations of zinc in the wool at shearing and on yellowness after challenge, were calculated as the differences between the two groups on each farm dipped with zinc sulphate and the control group. The relationship between these differences in zinc concentration and in yellowness was examined by regression analysis.

RESULTS

On-farm

Across all treatments and farms, the mean concentration of zinc in the fleece before treatment was 78.7 mg/kg (range 67-92 mg/kg). Dipping once with zinc sulphate increased the mean concentration of zinc in the wool at shearing to 421 mg/kg (116-1140 mg/kg). A second zinc treatment increased the mean concentration further to over 800 mg/kg (143-1920 mg/kg). On two of the farms, there was an increase in the concentration of zinc in the wool of the control group between dipping treatment and shearing (Table 2). Presumably this reflected some cross contamination between the treatment groups. The reasons why the effects of dipping with zinc sulphate on concentrations of zinc in the wool at shearing were much higher on Farm 4 than on the other three farms are unclear, but could relate to the different application methods used. Overall the concentrations of zinc at shearing do not appear to be related to the staple length when treatments were applied (Table 2).

On Farms 1 and 2, dipping with added zinc sulphate had no effect on the yellowness of the main lines of wool and on Farm 4 the differences in yellowness between

TABLE 2: Effect of dipping sheep with zinc sulphate on the concentration of zinc in wool and staple length of mid-side samples collected before treatment, and at shearing.

Farm	Occasion	Concentration of zinc in wool (mg/kg)			Staple length (mm)
		Control	Dipped		
			Once	Twice	
1.	Before treatment	73	70	78	73.4
	Shearing	86	182	252	107.5
2.	Before treatment	77	74	67	53.2
	Shearing	131	246	907	88.8
3.	Before treatment	84	80	81	94.8
	Shearing	77	116	143	151.3
4.	Before treatment	92	86	82	120.5
	Shearing	321	1140	1920	na

na - no samples collected at shearing

TABLE 3: Effect of dipping sheep with zinc sulphate on tristimulus (Y-Z) (base yellow) of wool from main fleece lines.

Farm		Control	Dipped		LSD	Significance
			Once	Twice		
1.	Sheep shorn	343	257	317		
	Main line	6.3	6.1	6.3	0.40	NS
	Oddments	12.7	11.2	12.0	1.37	†
	Combined[1]	7.9	7.3	7.7	0.60	NS
2.	Sheep shorn	18	200	146		
	Main Line	4.2	4.1	4.3	0.82	NS
3.	Sheep shorn	99	90	84		
	Main line	7.3	6.0	6.7	1.11	†
	Oddments	12.5	11.3	11.9	1.08	†
	Combined[1]	9.0	7.8	8.5	0.7	**
4.	Sheep shorn	400	83	85		
	Main line	4.2	3.8	4.3	1.1 (95% CI)	

1. Data from main and oddments lines analysed together, removing differences between lines as a block.

treatment groups were within the 95% confidence interval for the test (Table 3). On Farm 3, the effect on yellowness of both the main line and the oddments of dipping once with zinc, approached significance (P = 0.075 and 0.094, respectively). When the data for these two lines were analysed together, removing the differences between the main line and the oddments line as blocks, the reduction in yellowness of the wool from dipping once with zinc was highly significant (P<0.01).

In vitro

The effects of zinc dipping on tristimulus Y (brightness), Z and (Y-Z) (yellowness) after incubation are given in Table 4. As there were no interactions between zinc sulphate dipping and the solution used to spray the wool before incubation, only the main effects of zinc sulphate dipping and spraying solution are given. On Farm 1 the effect of dipping in zinc sulphate on yellowness after incubation approached significance (P=0.092). The effect of zinc dipping on tristimulus Y and Z (but not tristimulus (Y-Z)) after incubation was highly significant on Farm 2. On Farm 3 zinc dipping had no effect on any tristimulus values after incubation. The effects on all three tristimulus values were highly significant on Farm 4.

There was a highly significant relationship across all farms for the differences between treated and control groups in the concentration of zinc in the wool at shearing and post-challenge yellowness:

$$\Delta Y\text{-}Z = 0.06\ (\pm 0.2) - 0.0017\ (\pm 0.0003) \times \Delta Zn$$

$$R^2 = 83.4$$

Where: ΔY-Z, Δ Zn are the differences in post-challenge yellowness (tristimulus (Y–Z) and zinc concentration (mg/kg) in the wool at shearing, respectively, between wool from sheep dipped with zinc sulphate (once or twice) or from the control sheep.

Inclusion of yellowness of the wool from the control group had no effect on this relationship. However, as shown in Figure 1, this relationship was dependent on the data from Farm 4.

Increases in tristimulus Y, Z and decreases in tristimulus (Y-Z) from spraying the wool with zinc sulphate solution before the incubation challenge were all highly significant from all four farms (Table 5).

DISCUSSION

This trial has shown that under some circumstances significant reductions in wool yellowness may be achieved by including zinc sulphate in the solution when dipping. Interestingly, in no case was the effect on base colour of dipping twice greater than that of dipping once. Presumably the second dipping, usually in February or

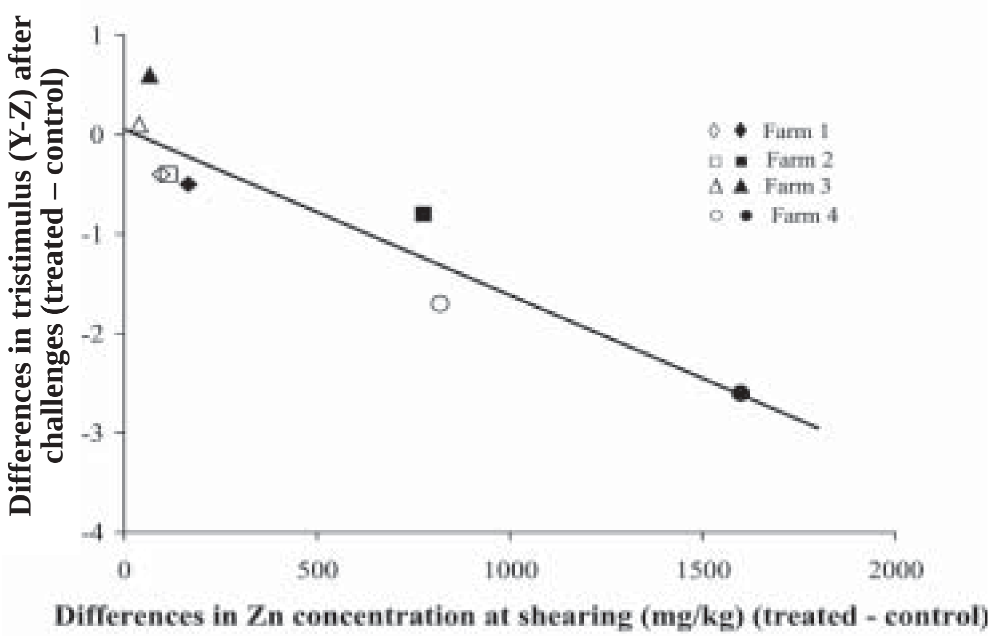
TABLE 4: Effect of dipping sheep with zinc sulphate on colour of wool (tristimulus value) from main fleece lines after incubating at 40°C, 100% RH for six days.

Farm	Tristimulus variate	Control	Dipped		LSD	Significance
			Once	Twice		
1.	Y	45.9	45.7	45.6	1.68	NS
	Z	35.2	35.4	35.4	1.91	NS
	Y-Z	10.7	10.3	10.2	0.44	†
2.	Y	48.3	49.2	50.0	0.71	**
	Z	39.4	40.7	41.9	1.28	**
	Y-Z	8.9	8.5	8.1	1.13	NS
3.	Y	48.8	48.4	48.7	1.66	NS
	Z	36.9	36.3	36.2	1.96	NS
	Y-Z	11.9	12.0	12.5	0.73	NS
4.	Y	49.4	51.5	52.7	1.50	**
	Z	38.5	42.4	44.0	1.63	***
	Y-Z	10.9	9.2	8.3	1.01	**

TABLE 5: Effect of spraying wool from main fleece lines with with either water or zinc sulphate on colour of wool (tristimulus value) after incubating at 40°C, 100% RH for six days.

Farm	Tristimulus variate	Sprayed with: Water	Sprayed with: Zinc sulphate	LSD	Significance
1.	Y	43.8	47.7	1.37	***
	Z	32.9	37.8	1.56	***
	Y-Z	10.9	9.9	0.36	***
2.	Y	47.6	50.7	0.58	***
	Z	37.6	43.7	1.05	***
	Y-Z	10.0	7.1	0.92	***
3.	Y	45.9	51.4	1.35	***
	Z	32.8	40.1	1.60	***
	Y-Z	13.1	11.3	0.59	***
4.	Y	48.8	53.6	1.23	***
	Z	38.2	45.3	1.33	***
	Y-Z	10.6	8.3	0.86	***

FIGURE 1: Difference (treated minus control) in the concentration of zinc in wool at shearing and wool yellowness after incubating at 40°C, 100% RH for six days.
Open symbols represent treatments dipped once.
Closed symbols represent treatments dipped twice.



early March, increased the humidity in the fleece for a time, increasing the environmental challenge so resulting in increased development of yellow discoloration. There were differences between farms in their locations, the breeds and numbers of sheep used, timing of applications of zinc sulphate and of shearing, application methods and concentrations of zinc in the wool at shearing. In spite of these differences, the yellowness of the wool in the groups of sheep dipped once with zinc sulphate was in all cases less than that of wool from the control group, although on only one farm did the difference reach statistical significance.

For two of the four farms, zinc dipping resulted in significant increases in tristimulus Y, Z or reductions in tristimulus (Y-Z) after a laboratory challenge designed to maximise the degree of yellowness development (Aliaga *et al.*, 1996; Reid, 1993). When the wool was sprayed with zinc sulphate solution rather than water before incubation, there were highly significant reductions in yellowness. These results indicate that zinc sulphate can reduce the propensity of wool to yellow. However, the yellowness of the main lines of wool was greater after incubation than before, indicating that the yellowness of the wool had not reached its full potential on any of the four farms. The on-farm effect of dipping with zinc sulphate on the yellowness of wool is likely to be expressed only when the environmental challenge is sufficient to maximise the extent of yellow discoloration. In this trial the effect of dipping with zinc sulphate on wool yellowness was significant only on the farm where the yellowness of wool from the control group was greatest (Farm 3).

Significant positive correlations have been reported between zinc concentrations in suint and propensity to yellow, as determined by the depth of yellowness of an acetone extract of suint after incubation (Aitken *et al.*, 1994). Sumner (2002) reported that the concentrations of calcium, sodium, potassium and zinc in clean wool explained 89% of the variation in base yellowness, with the zinc concentration being positively related to yellowness. The range of zinc concentrations in greasy wool described in this paper, where zinc was added by dipping with zinc sulphate solution, was larger than that reported by Sumner (2002). In the present trial the proportion of the added zinc either absorbed into the wool fibre or remaining in the suint is not known.

In the present trial, zinc applied to the wool resulted in variable increases in zinc concentrations in the greasy wool harvested at shearing, and these were negatively correlated with the differences between the control and treated mobs in the propensity of the wool to yellow. This relationship was, however, dependent on the data from one farm (Farm 4) where the concentration of zinc in the wool after dipping was considerably higher than on the other farms. Additional zinc sulphate, added before incubation in the laboratory challenge, reduced the propensity of the wool to yellow. The effect of zinc on propensity to yellow may be concentration dependent. At low concentrations, the relationship between zinc and propensity to yellow appears to be positive, while at higher concentrations it appears to be negative.

The mechanisms of these actions are obscure, and could involve chemical effects on the suint or the wool fibre, or the depressing effect of high concentrations of zinc on bacterial growth. Relatively high concentrations of zinc in the suint could inhibit bacterial growth, improving wool yellowness when environmental challenge is high.

The results of this trial suggest it may be possible to develop appropriate treatments to reduce the propensity of wool to yellow and, hence, the degree of yellow discoloration within individual wool clips. Further work is required to optimise methods to increase the zinc concentrations of wool to allow the results reported in this paper to be more widely used.

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APPENDIX

Members of the International Wool Textile Organisation, which includes New Zealand, have agreed that as from 3 December 2002 an alternative system of specifying wool colour from that previously used in New Zealand (NZS8707:1984) will be introduced progressively. Two colour values will appear on each Test Certificate until 1 July 2004, after which values for the alternative system only will be shown. The IWTO colour test method has been recently amended (IWTO-56-02) in line with these proposed changes.

NZS8707:1984 used a Waring Blendor to clean wool samples, calibrated the instrument to measure the Tristimulus values with reference wool and used illuminant C and 2° observer angle colour space ((WB)X_w, (WB)Y_w, (WB)Z_w). The new system will clean the wool in a core test scour, the instrument used to measure the tristimulus values will be calibrated with certified tiles and illuminant D65 and 10°observer angle colour space (X_t, Y_t, Z_t) will be used.

Data may be interconverted between the two colour spaces according to the following regression relationships:-

$X_t = 3.2341 + 0.9783\ (WB)X_w$

$Y_t = 0.9288 + 1.0458\ (WB)Y_w$

$Z_t = 2.2855 + 0.8760\ (WB)Z_w$

Tristimulus (Y-Z) is calculated in each case as the difference between the relevant tristimulus Y and tristimulus Z.

REFERENCE

IWTO-56-02. Method for the measurement of colour in raw wool.