A BREEDING GOAL TO IMPROVE THE WELFARE OF SHEEP

D R Scobie[†], A R Bray and D O'Connell

AgResearch, PO Box 60, Lincoln 8152, New Zealand

[†] Contact for correspondence and requests for reprints

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Abstract *Animal Welfare 1999, **8:*** 391-406

A polled sheep with a short tail, and devoid of wool on the head, legs, belly and breech, has been proposed as a breeding goal (Scobie et al *1997). This paper examines the practical and welfare implications of such an objective. Mean shearing times were significantly* ($P < 0.001$) *slower for control Romney (97s) and Coopworth (88s) ewe hoggets compared to times for both breeds after they were 'trimmed' to resemble the breeding goal (47s). Romney wethers were slower to shear than ewes* ($P < 0.001$), *but trimmed wethers (53s) were much faster to shear than the untrimmed controls (99s). Trimmed sheep produced less wool (pooled mean weights of fleece wool for trimmed sheep vs total wool for controls being 2.5 vs 3.5 kg;* $P < 0.001$), *half the difference (ie 500g) consisting of lower value oddment wools from the untrimmed controls. Tails were docked to 0, 20, 40, 60, 80 and 100 per cent of the distance between the base of the tail and the hock of Perendale lambs, and 0, 20, 40 and 60 per cent on Coopworths. More dags accumulated as the tail stump increased in length, although significance was dependent on the time of year and management system. No flystrike (cutaneous myiasis) was observed in Perendales given physical and chemical protection, while a small proportion of all tail lengths were flystruck in Coopworths given only physical protection. When shorn as hoggets, the time taken to shear Perendale ewes increased with increasing tail length* ($P < 0.001$). *Provided the undocked short tail is bare of wool, the proposed breeding goal should deliver an economic solution to sheep breeders attempting to satisfy markets conscious of chemical residue and animal welfare issues in the new millennium.*

Keywords: *animal welfare, dags, fleece cover, flystrike, tail length*

Introduction

Wild sheep are generally short-tailed with a short hair or wool fleece that is moulted annually. Following domestication, the incidence of fleece shedding has been reduced, and the pattern of fleece coverage of the body and the length of the fleece have increased. Long tails seem to be very common in domesticated breeds, although the purpose and origin of this trait is unclear. The exceptions are the North European short-tailed breeds and the fat-tailed and fat-rumped breeds. Horns have disappeared in some breeds, presumably for ease of management. However, certain breeds (like the Merino) have horns in the males only, while they are present in both sexes in other breeds and may be an important selection criterion in breeds like the Dorset Horn. Many European breeds are covered in wool with a long tail and no horns, and a generalized example of such a modern sheep breed is presented in Figure 1 (with the tail removed).

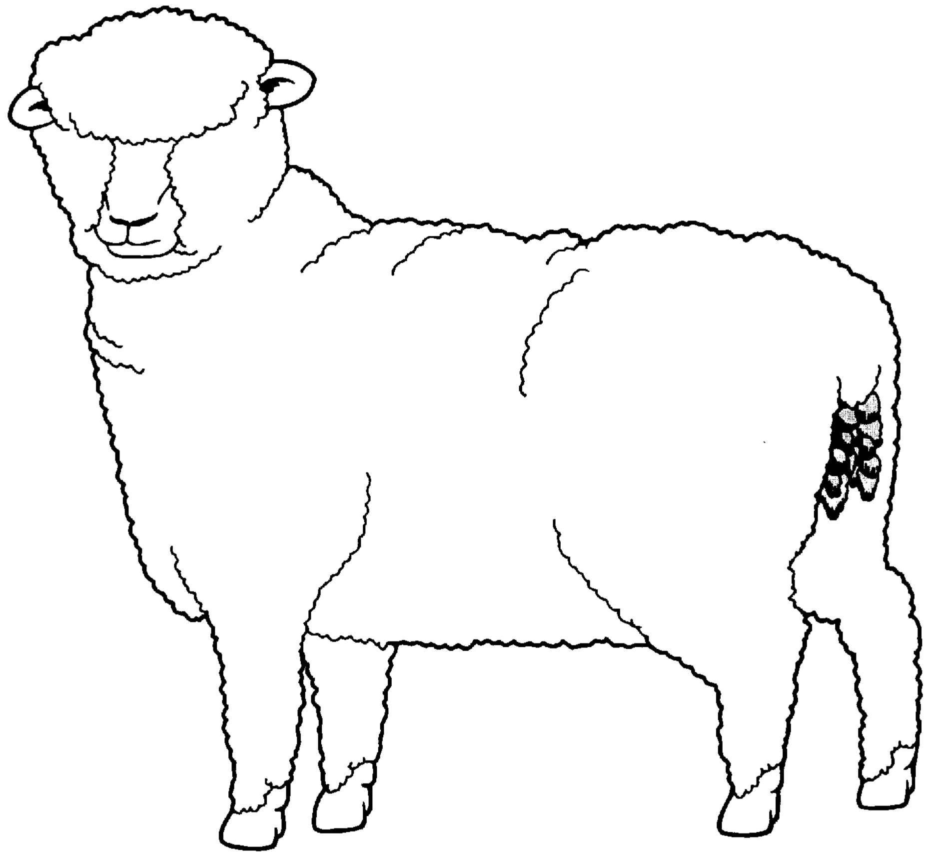

Figure 1 **An illustration of a generalized sheep raised for wool production and lambs.**

New Zealand sheep producers generally amputate or 'dock' lambs' tails to reduce dag accumulation and, therefore, flystrike (cutaneous myiasis). Experimental selection of Romneys with short tails has met with limited success as some of the genes are lethal, causing congenital deformities akin to spina bifida (Carter 1976). Varied effects have been achieved in Merinos (James *et al* 1991a, b). The North European short-tailed sheep breeds could almost be regarded as a subspecies that all have short tails. It is a very simple procedure to cross-breed and select for short tails (Branford-Oltenacu & Boylan 1974; Scobie unpublished data). A genetically short-tailed sheep could readily be retrieved from such breeds.

The scientific community has emphasized selection for resistance to intestinal parasites; however, much of the selection pressure has been aimed at enhancing performance. Woolaston (1998) suggested that improving resistance and other traits will become very important as consumers demand food and textiles free of chemical residues. Our prediction is that consumers will follow current trends and demand production systems that are considerate to animal welfare (Scobie *et al* 1997).

Mulesing is a drastic surgical operation used to reduce the number of skin folds and increase the area of bare skin around the perineum of Merino sheep. It was developed in the 1930s and is now in widespread use throughout Australia. The objective of mulesing is to reduce faecal and urine staining of the fleece, and thereby reduce the amount of flystrike.

In New Zealand, Romney sheep are not mulesed, but the wool around the breech is kept short by a shearing procedure called 'crutching'. Sometimes only the faecal contaminants, or 'dags' are removed by a shearing procedure called 'dagging', especially prior to shearing, to keep contaminants out of the shearing facility. Either procedure is conducted at least once, and commonly two or three times, a year. Depending on the time of shearing, and considering that some sheep are shorn every 8 months in New Zealand, crutching may be done prior to mating or during periods of peak flystrike risk. 'Pre-lamb crutching' is a specialized operation to remove wool from around the breech and udder. This exposes the udder so that lambs can locate the teats more readily, cleans around the breech in case assistance is required during birth and reduces dag accumulation during lactation when the throughput of feed of high moisture content is increased. The East Friesian breed, recently introduced to New Zealand, naturally has both a tail and patch around the tail that are bare of wool. Although the inheritance of this trait has not been reported, it is also highly desirable.

When crutching, the sheep producer may also use the opportunity to remove wool from the face of the animal. A shearing procedure is also used to remove wool from the cheeks and over the top of the head, and has various names such as 'eye-clipping' or 'wigging'. The objective is to remove wool from around the eyes to improve the sheep's vision and to reduce the chance of grass seeds or other materials working their way from the wool into the eyes. There are numerous breeds and animals within breeds that are not encumbered by facial wool: a characteristic which could be harnessed by cross-breeding and selection respectively.

The results of Rathie *et al* (1994) are an excellent demonstration of the flystrike reduction that is possible with cross-breeding. The Wiltshire Horn sheds its fleece annually and has a relatively large bare area of skin around the perineum. When crossed with the Merino, the proportion of flystruck sheep during a 3-year period was reduced from 35 per cent in the pure Merino control to 5 per cent in the Wiltshire Horn x Merino cross. This high level of flystrike prevailed despite the fact that the pure Merinos were tail docked, mulesed and crutched, whereas the Wiltshire Horn x Merino cross were only docked. Clearly, the difference in crutching and mulesing confounds this experiment from a scientific point of view, but from shepherding and welfare perspectives there are obvious reasons to cross-breed or select for traits that will protect sheep from flystike.

The pursuit of aesthetic and production goals has, in some sheep breeds and management systems, resulted in animals that require a high degree of husbandry to survive and reproduce. Assistance at birth, intensive care of newborn lambs, and susceptibility to parasites and diseases have become common in sheep husbandry, to the point where the welfare of such sheep is dependent on intervention from humans. Scobie *et al* (1997) described a breeding goal based on traits that would minimize or eliminate the need for animal husbandry practices like tail docking, mulesing, eye-clipping, crutching and dagging. The breeding goal is best described visually by Figure 2; but can be stated as a polled sheep

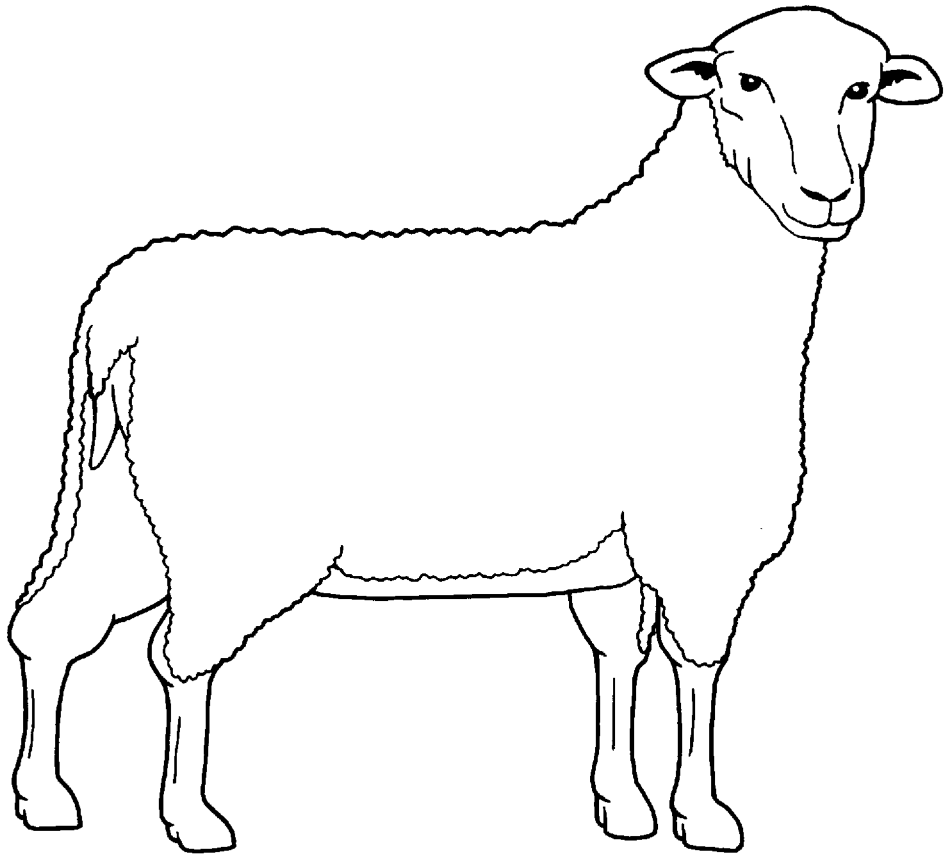

Figure 2 An illustration of the breeding goal to improve the welfare of sheep.

with a short tail, which is devoid of wool on the head, legs, belly and breech. The experiments outlined below were designed to model the losses and gains associated with this breeding objective.

Materials and methods

All experiments were carried out according to the *Code of Ethical Conduct for Animal Experimentation within the New Zealand Pastoral Agricultural Research Institute Inc* (AgResearch 1993); and all experiments were approved by the AgResearch Animal Ethics Committee (Approval numbers 97/11 and 97/15, respectively).

Tail length and dag score

Normal docking practices in New Zealand tend to leave very short tail stumps or no tail stump at all. The following experiments were designed to test the effect of increasing tail length on dag accumulation.

Perendales

Perendale sheep are regarded as a relatively hardy breed developed by crossing the Cheviot and Romney. Perendale lambs (n = 158), born between 4 and 21 September 1997, were randomly allocated to six groups (n = 29, 29, 28, 26, 24 and 22) at tail docking (26 September 1997). The shortest possible tail length treatment (0%) was applied to one group, by placing a rubber ring around the tail at the point where the tail met the body. The long-tail treatment (100%) was produced by holding either leg at right angles to the spine, holding the tail straight and placing a rubber ring on it at the point where it touched the hock. Intermediate length treatments were created by docking the tail at either 20, 40, 60 or 80 per cent of the distance from the base of the tail to the hock. All lambs were run together with the dams between docking and weaning, after which the male and female lambs were separated. All lambs were treated with chemicals for internal and external parasite control. (On 17 November, 10 December, 20 January, 20 February, 15 April and 5 June they were drenched with Vetdectin® [Monodectin 0.2mg kg^{-1}; Cyanamid of New Zealand Ltd, Auckland]; and they were dipped on 10 December and 20 February with Vetrazin® [Cryomazine 100 mg kg^{-1}; Novartis, Auckland].)

The lambs were assessed for 'dag score' on 9 December 1997, 20 January 1998, 15 April and 4 June. This score ranged from 0 (no dags) to 5 (excessive dags) and was based on the scores illustrated by Larsen *et al* (1994). As far as possible, the dag score was calculated by ignoring the tail itself and considering the area and severity of dags around the breech. The lambs were crutched on 10 December 1997, shorn on 21 January 1998 and crutched again on 5 June. None of the lambs were flystruck during the period of observation. A generalized linear model (Genstat 5 1997, release 4.1; Lawes Agricultural Trust, Hertfordshire, UK) was fitted to the dag score data, using multinomial responses and ordered categories.

Coopworths

The Coopworth originated from a cross between the Romney and the Border Leicester, and has since been selected for high reproductive performance. A group of Coopworth lambs (n = 196) with a mean birth date of 19 September 1997, were randomly allocated to the four shortest of the above treatments at docking (15 October 1997). The lambs were run with their dams until weaning at 3–4 months of age and then run as one mob, since the scrotums of the male lambs were shortened using rubber docking rings to render them infertile.

The lambs were scored for dags on 9 December 1997, 15 January 1998, 19 February and 24 March. All male lambs over 35.5kg were sold for slaughter on 24 March. The remaining males and all females (n = 95) were scored for dags on 15 April, a small number of females selected as replacements (n = 50), and all remaining males and females (n = 45) sold for slaughter. All lambs (n = 196) were crutched on 9 December 1997, 15 January 1998 and 24 March, but only those with dags were crutched on 19 February. The presence of flystrike was recorded on every occasion, but the presence of flystrike in any lamb was taken as the signal that all lambs needed crutching. No insecticide protection could be used on these animals because of their 'organic' status, and crutching was, therefore, the only method available to control flystrike and minimize suffering. A generalized linear model was fitted to the dag score data using multinomial responses and ordered categories. The outcome of this analysis was very similar to that for an analysis of variance (ANOVA), reported below. The ANOVA was preferred, since it was much simpler to report the mean and variation and to determine the effect of sex and the effect of increasing tail length using polynomial contrasts.

Time required to shear

The following experiment was designed to test the difference between the average time to shear a sheep with a fleece pattern like that in Figure 2 or like the New Zealand Romney in Figure 1. It could be argued that Figure 1 represents the extreme case of a woolly-faced Romney, but these are not uncommon in New Zealand and were relatively frequent in the flock we studied.

Romney wether hoggets (n = 80), Romney ewe hoggets (n = 68) and Coopworth ewe hoggets (n = 144) were weighed and allocated to one of two treatment groups at random within each liveweight class. All these animals had been shorn as lambs 10 months previously. One group was then shorn around the head, legs, belly and an area extending for approximately 50mm around the anus and over the tail. The remaining fleece pattern resembled that in Figure 2. This group was referred to as the 'trimmed' treatment. Only the dags were removed from the 'untrimmed' animals in line with common New Zealand practices of preparation for shearing. Three other groups of ewe hoggets were also included, none of which were trimmed: a group of Romneys (n = 18), some Perendales (n = 19) and some first-cross Poll Dorset x Romney (n = 19); only the Romneys had not been shorn as lambs.

The following day, all animals were shorn by two shearers. Wool types within breeds were assumed to have been randomly allocated, and the shearers were instructed to remove all the wool from each animal and make no changes in the type of equipment they were using. A randomized block design was chosen as the most efficient way of determining whether a shearer improved in technique while shearing trimmed sheep, with which (s)he would be relatively unfamiliar. The number of forward strokes (or 'blows') of the shearing handpiece and time taken to shear each hogget were recorded and the resultant weight of good quality fleece wool and oddment wools (bellies, skirtings, locks, crutchings and head wool) were determined. The data for number of blows and time taken to shear were analysed using regression, allowing for breed, sex, shearer, observer and liveweight, before fitting the treatment effects.

Shearing and tail length

The Perendale lambs from the tail length experiment described above were shorn as lambs in January 1998 and again as hoggets in August of the same year. At hogget shearing, 64 ewes were shorn by one shearer in random order. The liveweight, fleece weight, number of blows and time taken to shear each sheep were recorded. The data were analysed by fitting polynomial contrasts to the means in the ANOVA.

Crutching and tail length

On one dag scoring date, 12 lambs with a dag score of 0 were selected from each tail length treatment in the Perendales. From the Coopworths, 12 lambs with a dag score of 0 and 12 with a score of 2 or 3 were selected from each tail length treatment. The total time to crutch a dozen lambs in each category was recorded. The breeds, tail length and dag score were not randomized, and sex was not recorded.

Results

Tail length and dag score

Perendales

The Perendale lambs accumulated very few dags throughout the entire monitoring period. Indeed, on 20 January 1998, just two lambs had dags and these were given a dag score of only 1. On 4 June, one-third of the lambs had developed dags; five were given a score of 3 and two a score of 4 – yet there was no effect of treatment. The distribution of dag scores departed significantly from normal. Mean dag scores, their significance at the 5 per cent level and least significant differences (none significant at 5%) for the four occasions are displayed in Table 1. There was no significant effect of tail stump length on dag score when analysed using the generalized linear model.

Table 1 **Mean dag score of Perendale lambs with tails docked to 0, 20, 40, 60, 80 and 100 per cent of the distance between the base of the tail and the hock (length). The least significant differences (LSD) at 5 per cent (all non significant) and significances (at P < 0.05) using a generalized linear model are shown. ns - not significant.**

		Score		
Length	**9 Dec**	**20 Jan**	**15Apr**	**4 Jun**
0 %	0.25	0.00	0.15	0.48
20 %	0.34	0.00	0.14	0.59
40 %	0.07	0.00	0.19	0.41
60 %	0.27	0.00	0.12	0.19
80 %	0.13	0.04	0.21	0.71
100 %	0.18	0.05	0.23	0.68
LSD	0.25	0.06	0.26	0.48
Significance	ns	ns	ns	ns

Coopworths

From Table 2 it is evident that increasing the length of the tail stump increased the accumulation of dags for the Coopworth lambs. There was no significant difference between length treatments on 9 December 1997 (P = 0.524), 15 January 1998 (P = 0.068) or 24 March (P = 0.088). However, the trend was similar to 19 February (P < 0.001) and 15 April (P = 0.028), when dag score tended to increase with tail length. On the first two sampling dates there was no significant difference between the sexes, but on 19 February (P = 0.034) and 24 March (P < 0.001) male lambs had accumulated significantly more dags than ewe lambs (respective mean dag scores; 0.9 vs 0.7 and 1.4 vs 0.9). This situation was also observed on 15 April, when many of the male lambs had been sold (1.0 vs 0.5; P < 0.001).

Table 2 **Mean dag score of Coopworth lambs with tails docked to 0, 20, 40 and 60 per cent of the distance between the base of the tail and the hock (length). The least significant differences (LSD) at 5 per cent and significances (at P < 0.05) using a generalized linear model are shown. ns - not significant; *P < 0.05.**

			Score		
Length	**9 Dec**	**15 Jan**	**19 Feb**	**24 Mar**	**15 Apr**
0 %	1.09	1.05	0.33	0.88	0.55
20 %	1.05	1.27	0.76	1.07	0.84
40 %	1.21	1.47	0.84	1.18	0.74
60 %	1.31	1.62	1.21	1.34	1.08
LSD	0.49	0.48	0.36	0.36	0.35
Significance	ns	ns	*	ns	*

Flystrike was observed among the Coopworth lambs in December 1997, January 1998, and February 1998, with only 15, 17, and 3 lambs affected respectively; and a single lamb was flystruck in March. Given the small numbers of animals affected, there was no significant treatment or sex effect.

Time required to shear

Trimmed sheep required around half as many blows to shear as untrimmed controls ($P < 0.001$, Table 3). This number of blows was accomplished much faster, with the trimmed sheep taking just over half the time it took to shear the controls ($P < 0.001$). Breed affected both the number of blows ($P < 0.001$) and the time taken to shear each hogget ($P < 0.001$). The Perendales were intermediate between Romneys and Coopworths in the number of blows and time taken, but the Poll Dorset x Romney and the woolly Romneys required more blows and more time to shear (Table 3). These results contributed to the highly significant effect of breed on blows ($P < 0.001$) and shearing time ($P < 0.001$).

Table 3 The number of animals (n), mean number of blows and mean time per animal (s) to shear trimmed and untrimmed hoggets previously shorn or unshorn (woolly) as lambs, and the mean liveweight (kg), and weight (g) of fleece wool, oddment wool and total wool removed.

Treatment	Breed	Sex	n	Blows (no)	Time (s)	Fleece (g)	Oddments (g)	Total wool (g)	Liveweight (kg)
Trimmed									
	Coopworth	ewe	72	35.7	47.2	2494	842	3335	47.8
	Romney	ewe	34	35.4	47.3	2631	1155	3786	49.7
	Romney	wether	40	38.8	52.7	2711	1223	3934	52.6
Untrimmed									
	Coopworth	ewe	72	74.9	88.1	2883	469	3352	48.0
	Romney	ewe	34	80.7	96.9	3224	513	3737	49.2
	Romney	wether	40	84.8	99.2	3356	568	3924	52.1
	Perendale	ewe	19	77.3	92.1	2369	378	2747	40.8
	Poll Dorset x Romney	ewe	19	90.6	107.8	2597	451	3048	53.8
	Romney (woolly)	ewe	18	86.7	104.6	4057	646	4704	49.8
Pooled standard deviation		-	-	***6.1***	***11.1***	***340***	***123***	***409***	***6.0***

In terms of total wool removed from the animal, there was no treatment effect ($P = 0.974$). However, there was a significant breed effect ($P < 0.001$), with the total wool removed in ascending order: Perendales, Poll Dorset x Romneys, Coopworths, Romney ewes, Romney wethers and finally the Romneys not shorn as lambs. A greater mass of oddment wool was removed from trimmed sheep during the trimming and shearing procedures than from the untrimmed controls ($P < 0.001$). Since the total wool removed was the same for both trimmed and untrimmed hoggets, and there were less oddment wools in the untrimmed, less fleece wool was recovered from the trimmed hoggets ($P < 0.001$). Trimmed Coopworths produced almost 2.5kg fleece wool, while trimmed Romney ewe and wether hoggets produced 2.6kg and 2.7kg respectively. This was 390g, 593g and 645g less than their untrimmed counterparts, respectively. The Romneys not shorn as lambs carried 1kg of wool more than the Romney ewes that had been shorn as lambs. More time and more blows were

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required to remove the wool from the hoggets not shorn as lambs than for all but the Poll Dorset x Romney.

Shearing and tail length

There were significant differences in both liveweight (P = 0.034) and fleece weight (P = 0.089) between tail length groups of Perendale ewe hoggets at shearing. Given that the 20, 80 and 100 per cent treatments were similar in liveweight, there was no significant linear increase in liveweight (P = 0.178) or fleece weight (P = 0.438) with increasing tail length. Fleece weight and liveweight were correlated (r = 0.538). Covariate analyses adjusting for both liveweight and fleece weight were performed, but neither indicated a significant effect on the number of blows or the time taken.

The number of blows to shear an average sheep in the three shortest tail length groups was similar, at around 41 blows. An extra 5 blows were taken for the 60 per cent treatment, 6 for the 80 per cent and 7 for hock length (ie 100%) tails ($P < 0.001$). There was also a significant linear increase in average time taken to shear a sheep as tail length increased ($P < 0.001$), from 60s for the shortest, to 72s for the longest (Figure 3).

Crutching and tail length

The results presented in Figure 4, for the interest of the reader, show the mean times taken to crutch 12 mixed-sex lambs with (Coopworths only) or without (Coopworths and Perendales) dags. This figure supports the results of the time taken to shear in the tail length treatments, in that longer tails slowed the removal of wool. It also seems that daggy tails were much slower to crutch than non-daggy tails.

Discussion

From these experiments modelling our breeding goal we can predict the following with confidence. The proposed fleece pattern will make the sheep faster to shear, assuming that the cross-breeding and selection required to reach this goal does not change wool characteristics beyond those of the sheep used here. However, if the tail is genetically shorter but left undocked, without increasing the amount of bare skin on and around the tail, more dags will accumulate relative to docked tails and the number of blows and time taken to shear each animal will increase. With a bare tail, these traits should reduce the incidence of flystrike, the need for tail docking and dagging and improve the ease of shearing.

From the tail length experiment, it is appears that the most appropriate tail length for minimizing the dagginess of New Zealand lambs would be no tail stump (0%) at all. Dag accumulation was least for this length, and dag score increased for Coopworth lambs with increasing stump length. This is in contradiction to the recommendations of Vizard (1994) who found that if the tail is docked too short, wool tends to hang over the anus and become soiled. This also occurred at the other end of the range they observed, where the tail tends to become too heavy to lift as the sheep ages, if left un-docked, and the tail becomes fatter and more covered in wool. This suggests a non-linear effect and Vizard (1994) recommended 'a 4-inch stump' as the most appropriate for Merino sheep. The results of the present experiment are for lambs only. The characteristics of the wool may play an important part. The wool of lambs, Merinos and Perendales is short and has a fibre and staple architecture that makes the staples stand erect, whereas the wool on adult Coopworths and Romneys tends to hang down. A curvilinear effect might become evident as the Perendale and Coopworth sheep used here grew older and carried a 12-month, adult fleece.

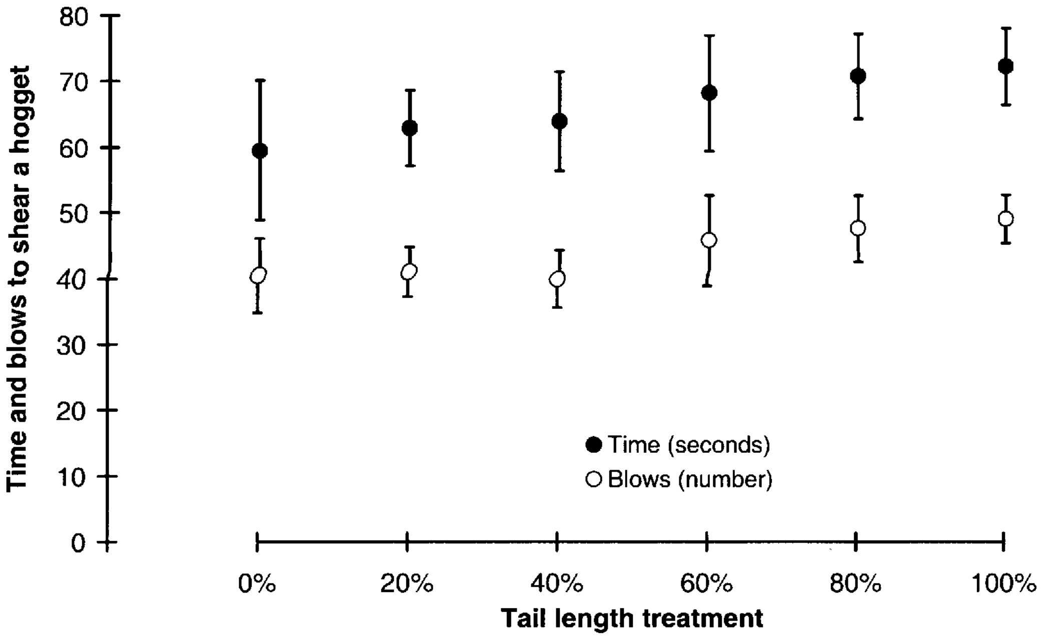

Figure 3 **The mean (and standard deviation) time and number of blows taken to shear Perendale ewe hoggets from the six different tail length treatments.**

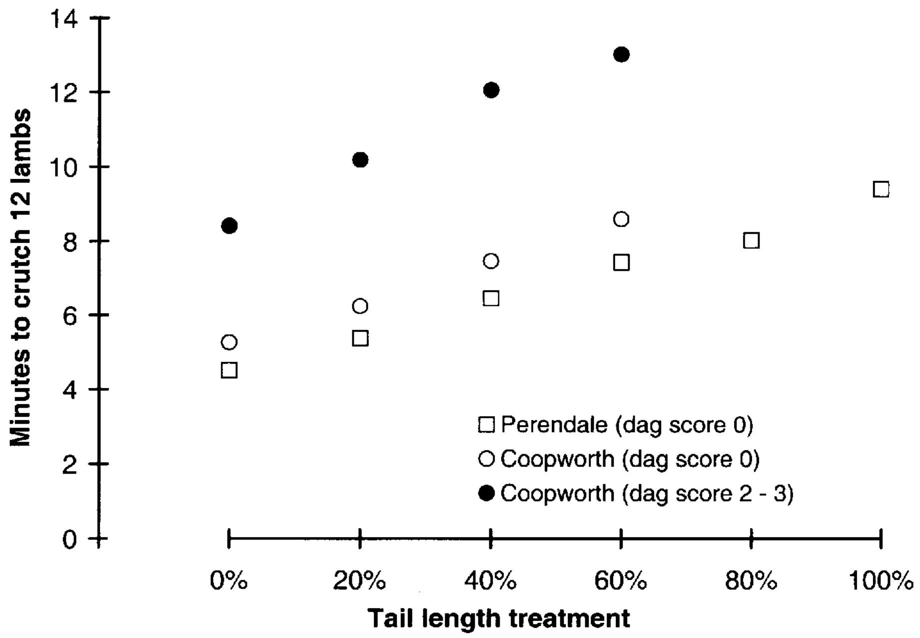

Figure 4 **The mean time taken to crutch 12 Perendale lambs without dags, or 12 Coopworth lambs with or without dags.**

One can speculate that New Zealand farmers, who tend to crutch more often and do their own crutching and dagging, would have noticed that longer stumps are slower to crutch and thus developed the tendency to dock tails shorter. In comparison, Australian sheep producers, who tend to employ people to crutch their sheep and pay per sheep irrespective of stump length, are less likely to feel the impact of longer tails. Squamous cell carcinoma of the vulva is also an important consideration in Australian Merino husbandry (Vandergraaff 1976). Because their wool grows relatively slowly, the sheep are subject to an intense amount of ultraviolet radiation, and the animals tend to be retained in the flock for extended periods of time due to the lower reproductive rate of Merinos. These cancers are less frequent under New Zealand conditions where the productive lifespan of the sheep is short, wool is longer and skin pigmentation is much darker.

Flystrike tends to be more prevalent in undocked lambs (French *et al* 1994a, b; Vizard 1994), since the increased dag and urine contamination of the wool predisposes the animals to flystrike. This was not observed in the current experiment, because the experiment was designed to minimize suffering. The indicator trait of dagginess would suggest that the Coopworths would be more likely to be flystruck as tail length increases. As noted (see, *Introduction)*, docking, mulesing, dagging and crutching are performed to minimize flystrike. The problem is, how to maximize selection for resistance to flystrike while these prophylactic measures are in place? Quite possibly, ram breeders could be expected to abstain from these treatments, or to cull against some indicator traits. Commercial producers who breed their own replacement ewes could use preventative treatments on all male lambs since these are destined for slaughter, use curative treatments in females as required, and select from those which did not require treatment. Such approaches would limit suffering in the short term to a small proportion of the flock – and balance economics and long-term animal welfare.

As the Coopworth lambs' age increased, a sex effect became apparent, with the wethers developing significantly higher mean dag scores. The reason for males accumulating more dags could be the difference in the bare area around the anus and vulva versus the anus alone. Mulesing produces a similar effect, with larger bare areas giving increased protection (Dun 1954). Australian work on Merino sheep (Watts & Marchant 1977; Watts & Luff 1978; Watts *et al* 1979) suggests that the tail should be long enough to cover the vulva in females and an equivalent length in males. At this length, the tail can be held up during defecation (and urination in females) and the caudal folds either side of the anus tend to direct the faeces away from the wool. There were no significant interactions between tail treatment and sex in the present experiments – but with further evidence there may be good reasons to undertake a different docking procedure for male and female lambs. Males are generally sold for slaughter as lambs, but replacement ewes may remain in the flock for several years.

From a strictly scientific point of view, we cannot compare the Perendale lambs with the Coopworths. The Perendales were treated with chemicals for internal and external parasite control, and run in different paddocks on the farm. They were crutched on the same days as the Coopworths, but more as a matter of convenience and protection than because it was necessary. The Coopworths were not treated with chemicals. Clearly, there are too many confounding variables for a credible between-breed analysis. From the sheep producers' (pragmatic) point of view, however, the situation appears very different. A flock of sheep that required crutching five times in the first 7 months of life to limit flystrike to 36 cases, may well be less desirable than another flock which were drenched once, dipped once and crutched three times for protection – and none of which were flystruck. As in the past, a producer would tend to favour the flock and husbandry system that did not suffer from flystrike, despite the long-term detrimental effect(s) on the sheep.

Sheep producers have always attempted to maximize production. They adopt management systems which might use one method to achieve many outcomes, say crutching to reduce flystrike and dagginess and improve wool quality; but they might also use many methods to achieve one outcome, like controlling flystrike using strategic shearing, crutching, dipping or jetting. In the past they have relied on a chemical arsenal to help them, and they have bred sheep that will produce high fleece weights, growth rates and lambing percentages in this environment. As they try to respond to the demand for chemical-free food, they have tended to rely on physical methods that are familiar to them, like crutching and mulesing. These physical methods will come under scrutiny with increased demand for improved animal welfare. Our suggested breeding goal is an animal that has been genetically docked, crutched and mulesed, so that the animal can cope without the aid of chemical and physical treatments.

The time required to shear individual sheep varies greatly. In Australia, Tierney (1980) found that shearing a Merino required 270s on average, but a Wiltshire Horn x Merino first-cross sheep could be shorn in less than half that time (123s). While these two breeds have different amounts of wool cover, other breed characteristics would have influenced shearing times. McGuirk *et al* (1981) found that the time required to shear each animal decreased with decreasing face cover, decreasing greasy fleece weight, the number of wrinkles, and liveweight in Merinos. The time taken to shear the breeds used here ranged from 88s for the untrimmed Coopworth ewes to 107s for the Poll Dorset x Romney. (Of course the ability of the shearer is important, the faster shearer in these trials averaged 89s over all the breeds, while the other was much slower at 102s. The average speed of the first two shearers on Perendales was 92s, while the shearer in the tail length experiment averaged 66s, including the tail.) Like McGuirk *et al* (1981), we would not support time taken to shear as a breeding objective. Shearing time varies with the pattern of wool cover, between shearers and between breeds, and it is very likely to be antagonistic to selection for finer fibres, higher fleece weight and, perhaps, the crimp of the wool. The pattern of fleece cover will be a much simpler breeding objective.

Coopworths and Perendales have less wool on the face and front legs than Romneys – being almost halfway between the depictions in Figure 1 and Figure 2. Accordingly, they required fewer blows, less time to shear and had lower fleece weights than Romneys. From the trimmed sheep model, it is clear that Romney and Coopworth ewe hoggets would both produce almost the same amount of fleece wool, and they would require the same number of blows and time to shear, if they had a fleece cover pattern like that in Figure 1. There would be some sacrifice of fleece weight with a pattern like that in Figure 1, but at the current value of New Zealand cross-bred wool, this would only be a loss of around NZ$1.00 per head. These animals would not necessarily be less productive, other than in terms of reduced fleece weight, and indeed some of the traits that we have prescribed are likely to be positively correlated with increased productivity. Based on the evidence from the available literature, we would expect higher lambing percentages and faster lamb growth rates from breeds with bare heads and legs. Although we might expect them to produce a lower fleece weight, when adjusted for the higher lamb performance they may actually produce relatively more wool (Cockrem & Rae 1966).

Given that the tail, even in the longest treatment, formed a very small proportion of the entire surface area of a Perendale hogget, it was surprising how much time this added to the shearing procedure. However, when one considers the fact that the tail is not a rigid structure, and it is very difficult to hold for safe mechanical shearing, the result makes more sense. Shearing the tail is also dangerous because the shearer is bent over and stretched out as far as possible, holding the tail in one hand and the shearing handpiece in another. Although the shearer may have experienced many different lengths of tail throughout his career, it is unlikely that (s)he would have had sufficient experience with longer tails to develop an appropriate technique. The courses available for shearer training in New Zealand certainly do not deal with techniques for shearing long tails, as they are uncommon. Although techniques and courses could be developed for longer tails, it would seem more sensible to select for bare tails.

Should we design animals for economic goals?

Wild sheep need to survive and reproduce in their environment. Domestic animals must not only survive and reproduce, but are also expected to produce in their environment. The shepherd has modified their environment by improving pasture and shelter, and by controlling predators and parasites. Throughout generations of sheep husbandry, shepherds have also noticed and bred from sheep that are either better producers or look distinctively different.

Rauw *et al* (1998) reviewed evidence that chickens, pigs and dairy cattle selected for improved production efficiency have developed behavioural, physiological and immunological problems and, therefore, that their welfare has deteriorated. Selection in sheep has certainly not attained the same rate of genetic 'improvement' as in other species, but increased susceptibility to flystrike and intestinal parasites provide evidence of similar trends. Ott (1996) referred to the selection of animals for appearance as 'Animal Illfare', but acknowledged that current trends towards selection for performance should result in animal form being more closely aligned with function. Simm *et al* (1996) reviewed some of the traits that could be considered in selection to improve the welfare of sheep under extensive conditions, such as litter size, fleece type, fat storage, disease resistance, maternal behaviour and grazing behaviour. These are valuable traits, but we believe that, for New Zealand, the traits we have nominated should receive a great deal of selection pressure to change the breeds from the depiction in Figure 1 to something resembling Figure 2, leaving fitness traits to natural selection.

Animal welfare implications

The proposed breeding goal gives our best prediction for the sheep that will suit the New Zealand environment. The results presented in this paper model a sheep that resembles this goal. However, these are simple models where the traits were changed, but the genotype was relatively constant (Romney, Coopworth and Perendale are closely related breeds). Responses among related traits may vary widely, for example both short-tailed and bare-headed breeds seem to be generally more fertile, but high reproduction may be a mismatch for the environment – and poor neonatal survival would certainly not be an improvement in welfare.

Kilgour and de Langen (1970) found that shearing at a slower rate elevated plasma cortisol more than shearing at a conventional speed. Hargreaves and Hutson (1990a) found that crutching was a less stressful procedure than shearing, although it was not clear whether this was due to the shorter time taken to crutch a sheep than to shear it. Sheep that resemble the new breeding goal will take less time to shear, and each sheep will be restrained for less time, thus potentially reducing animal stress. On the other hand, Hargreaves and Hutson

(1990b) claimed that there was no difference in the stressfulness of partial vs complete shearing. Up-ending (tipping the sheep over on its rump) for shearing was, by itself, found to be a stressful procedure (Hargreaves & Hutson 1990b). The proposed breeding goal could enable the development of novel shearing techniques or novel means of holding sheep for the shearing process, since the sheep will not need to be up-ended for clearing the belly and insides of the legs. Regardless of whether a faster shearing procedure once a year will be less stressful, there will be no need for two or three stressful crutching procedures between shearings, thus improving overall animal welfare.

The Finnish Landrace breed has a natural tail length that varies between the 40 per cent and 60 per cent length treatments imposed here (Scobie unpublished data). This could be left undocked if it were bare of wool. If a short tail was covered in wool, more dags would accumulate relative to a short bare tail and the incidence of flystrike would be expected to increase undesirably. The number of blows and time taken to shear each animal would increase slightly if wool were present on the longer tail, but the impact of this on animal welfare would be relatively slight.

The traits shown in Figure 2 will reduce flystrike, and, therefore, the need for docking or mulesing. Flystrike doubles plasma cortisol concentration (Shutt *et al* 1988), but tail docking can cause a fourfold increase in plasma cortisol, and mulesing a fivefold increase (Shutt *et al* 1987). In New Zealand, almost all lambs are currently docked and experience that stress, although very few are mulesed. It is doubtful that all lambs would become flystruck if not docked, but it is highly likely that some would be struck more than once during their lifetimes – and it is debatable whether flystrike or the preventative measures would be the greater stressors. The breeding goal presented here should eliminate the need for both tail docking and mulesing, and the few animals that do become flystruck should be culled.

The welfare of the animal shown in Figure 2 will be improved during shearing, and the additional stresses of crutching and dagging will be eliminated. Perhaps the most desirable outcome in terms of animal welfare will be the reduced risk of injury to the prepuce, teats, hamstrings, eyes, ears and the tip of the vulva. Although not investigated here, the breeding goal will also reduce the incidence of wool blindness and grass seeds that lodge in the eye. Neonatal lamb survival is also expected to improve as the lambs will have improved access to the udder and bare skin stimulates suckling behaviour (Billing & Vince 1987). Further experimentation will be required to test these hypotheses rigorously, as sheep approaching the breeding goal become available.

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References

AgResearch 1993 *Code of Ethical Conduct for Animal Experimentation within the New Zealand Pastoral Agricultural Research Institute Inc.* AgResearch: Hamilton, New Zealand

Billing A E and Vince M A 1987 Teat-seeking behaviour in newborn lambs. I. Evidence for the influence of maternal skin temperature. II. Evidence for the influence of the dam's surface textures and degree of surface yield. *Applied Animal Behaviour Science 18:* 301-325

Branford-Oltenacu E A and Boylan W J 1974 Inheritance of tail length in crossbred Finn sheep. *The Journal of Heredity 65:* 331-334

Carter A H 1976 Inherited tailessness in sheep. In: *Agricultural Research in New Zealand* pp 33-34. Annual Report of Research Division, Ministry of Agriculture and Fisheries: Wellington, New Zealand

Cockrem F and Rae A L 1966 Studies on face cover in the New Zealand Romney Marsh sheep. 1. The relationship between face cover, wool blindness, and productive characters. *Australian Journal of Agricultural Research 17:* 967-974

Dun R B 1954 A comparison between the radical mules operation and the modified mules operation. *The Agricultural Gazette 64:* 124-128

French N P, Wall R and Morgan K L 1994a Lamb tail docking: a controlled field study on the effects of tail amputation on health and productivity. *Veterinary Record 134:* 463-467

French N P, Wall R and Morgan K L 1994b Tail docking of lambs in the control of flystrike. *Veterinary Record 135:* 47

Hargreaves A L and Hutson G D 1990a The stress response in sheep during routine handling procedures. *Applied Animal Behaviour Science* 26*:* 83-90

Hargreaves A L and Hutson G D 1990b An evaluation of the contribution of isolation, up-ending and wool removal to the stress response to shearing. *Applied Animal Behaviour Science* 26*:* 103-113

James P J, Gare D R, Singh A W, Clark J P, Ponzoni R W and Ancell P M 1991a Studies of the potential for breeding short tail Merinos. *Wool Technology and Sheep Breeding 38:* 106-111

James P J, Ponzoni R W, Gare D R and Cockrum K S 1991b Inheritance of short tailedness in South Australian Merinos. *Proceedings of the Association of Animal Breeding and Genetics 9*: 404-407

Kilgour R and de Langen H 1970 Stress in sheep resulting from management practices. *Proceedings of the New Zealand Society of Animal Production 30:* 65-76

Larsen J W A, Anderson N, Vizard A L, Anderson G A and Hoste H 1994 Diarrhoea in Merino ewes during winter: association with trichostrongylid larvae. *Australian Veterinary Journal 71:* 365-372

McGuirk B J, Ponzoni R W, Atkins K D, Gilmour A R, Morley F H W and Maher L 1981. Factors influencing the time required to shear Merino sheep and its importance as a breeding objective. *Australian Journal of Experimental Agriculture and Animal Husbandry 21:* 387-394

Ott R S 1996 Animal selection and breeding techniques that create diseased populations and compromise welfare. *Journal of the American Veterinary Medical Association 208:* 1969-1974

Rathie K A, Tierney M L and Mulder J C 1994 Assessing Wiltshire Horn-Merino crosses: 1. Wool shedding, blowfly strike and wool production traits. *Australian Journal of Experimental Agriculture 34:* 717-728

Rauw W M, Kanis E, Noordhuizen-Stassen E N and Grommers F J 1998 Undesirable side-effects of selection for high production efficiency in farm animals: a review. *Livestock Production Science 56:* 15-33

Scobie D R, Bray A R and O'Connell D 1997 The ethically improved sheep concept. *Proceedings of the New Zealand Society of Animal Production 57:* 84-87

Shutt D A, Fell L R, Connell R, Bell A K, Wallace C A and Smith A I 1987 Stress-induced changes in plasma concentrations of immunoreactive β-endorphin and cortisol in response to routine surgical procedures in lambs. *Australian Journal of Biological Sciences 40:* 97-103

Shutt D A, Fell L R, Connell R, Bell A K, Wallace C A and Smith A I 1988 Effect of myiasis and acute restraint stress on plasma levels of immunoreactive β-endorphin, adrenocorticotrophin (ACTH) and cortisol in the sheep. *Australian Journal of Biological Sciences 41:* 297-301

Simm G, Conington J, Bishop S C, Dwyer C M and Pattinson S 1996 Genetic selection for extensive conditions. *Applied Animal Behaviour Science 47:* 47-59

Tierney M L 1980 Studies of Wiltshire Horn-Merino crosses. In*: Wool Harvesting Research and Development* pp 485-495. Australian Wool Corporation: Melbourne, Australia

Vandergraaff R 1976 Squamous-cell carcinoma of the vulva in Merino sheep. *Australian Veterinary Journal 52:* 21-23

Vizard A L 1994 Tail docking of lambs in the control of flystrike. *Veterinary Record 134:* 583

Watts J E and Luff R L 1978 The importance of the radical Mules operation and tail length for the control of breech strike in scouring Merino sheep. *Australian Veterinary Journal 54:* 356-357

Watts J E and Marchant R S 1977 The effects of diarrhoea, tail length and sex on the incidence of breech strike in modified mulesed Merino sheep. *Australian Veterinary Journal 53:* 118-123

Watts J E, Murray M D and Graham N P H 1979 The blowfly strike problem of sheep in New South Wales. *Australian Veterinary Journal 55:* 325-334

Woolaston R R 1998 Breeding livestock for reduced reliance on chemicals. *Wool Technology and Sheep Breeding 46:* 124-132