Proc. Assoc. Advmt. Anim. Breed. Genet. 20:53-56

CAN SELECTION FOR BRIGHTER, WHITER MORE PHOTOSTABLE WOOL REPLACE OXIDATIVE BLEACHING DURING WOOL PROCESSING?

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SUMMARY

Responses to selection were predicted for brightness, whiteness and photostability of Merino fleece wools using five common sheep breeding objectives based on Merino or Dual Purpose production systems. Genetic parameters for brightness, whiteness and photostability estimated from the Cooperative Research Centre for Sheep Industry Innovation's (Sheep CRC) Information Nucleus (IN) flock were used in the predictions. Breeding objectives with a high emphasis on reducing fibre diameter will generate small correlated improvements in both brightness and whiteness (0.15 and -0.16 T units respectively) however the responses achieved in 10 years are considerably lower than those required to render oxidative bleaching during processing unnecessary. Including brightness and whiteness as selection criteria produced slight improvements in the predicted response although the increases being just 0.01 across all indexes are unlikely to be of practical significance. Each of the indexes produced correlated improvements in photostability but are again of too low an extent (i.e. -0.05 to -0.22) to overcome the 3 T unit detrimental impact of bleaching on photostability, even when photostability was included as a selection criterion. Based on these predictions, the responses in brightness, whiteness and photostability achieved though the use of common Merino selection indexes are not sufficient to replace the routine use of oxidative bleaching of wool during processing.

INTRODUCTION

Bright, white and pastel shade products are essential for the growing markets for casual clothing, trans-seasonal knitwear, sports and leisurewear (Millington *et al.* 2013). Cotton and polyester fibres are both significantly whiter than Merino wool with typical yellowness (Y-Z) values of 2 and -4 respectively (Millington and King 2010) compared to a range of 6 – 11 for Merino wool (Millington *et al.* 2013). Brightness values > 71.5 and whiteness < 8.5 are considered desirable targets for Merino wool (Wood 2002), and as a result wool destined for use in bright white and pastel shade garments is always bleached with hydrogen peroxide during processing to improve its whiteness (Millington *et al.* 2013). The bleaching process improves brightness to between 80 to 85 T units and whiteness to between 3 to 3.5 T units (Millington *et al.* 2013). However peroxide bleaching has detrimental effects on photostability, as treated wool photoyellows to a greater extent (about 3 T units higher) than untreated wool (Millington *et al.* 2013), and handle and softness also deteriorate (become harsher) with treatment (Millington and King 2010). On-farm selection for brighter, whiter wool may provide an alternative to peroxide bleaching, though selection responses in the order of 5-10 T units for brightness and 5 T units for whiteness are necessary to produce similar brightness and whiteness values as the process of bleaching. This paper reports predicted responses to selection in brightness, whiteness and photostability for common Merino breeding objectives. The aim of the study was to determine whether sufficient improvement in both brightness and whiteness can be achieved through the use of common Merino selection indexes, making oxidative bleaching during processing unnecessary.

MATERIALS AND METHODS

Responses to selection were predicted using selection index methodology (Cameron 1997) following the procedure outlined by Mortimer *et al.* (2010). Three common breeding objectives based on Merino wool production systems were used (Merino 14%, Merino 7% and Merino 3.5%) as well as two used in dual purpose wool and meat enterprises (Dual Purpose 3.5% and Dual Purpose 7%). The different breeding objectives are based on micron premiums (calculated as the increase in the price of wool associated with a reduction of 1 micron in fibre diameter, expressed as a percentage) with higher percentages indicating a greater emphasis placed on reducing fibre diameter relative to wool production. The Dual Purpose breeding objectives have a higher emphasis on liveweight and reproduction than the Merino breeding objectives (Mortimer *et al.* 2010). The relative emphasis of each trait in each of the selection indexes is outlined in Mortimer *et al.* (2010). Predicted responses to selection were calculated for each of the then standard MERINOSELECT™ indices (Brown *et al.* 2007). Selections were based on 4 selection criteria (greasy fleece weight GFW; fibre diameter FD; fibre diameter coefficient of variation FDCV and; liveweight LWT) with responses predicted in the breeding objective traits as well as brightness, whiteness and photostability. All predicted responses were calculated over a 10 year period for a typical ram breeding flock without introductions of outside genetics. Responses in brightness, whiteness and photostability were monitored by assuming a relative economic value of zero.

The correlation structure for the breeding objective traits was based on Mortimer *et al.* (2009), preliminary estimates of genetic parameters for brightness, whiteness and photostability together with the measurement and analysis protocol are provided by Hatcher *et al.* (2010) and Hatcher *et al.* (2011). Updated estimates of the phenotypic variance, heritability and correlations (phenotypic and genetic) for brightness (σ^2=0.77, h^2=0.51), whiteness (σ^2=2.85, h^2=0.33) and photostability (σ^2=0.23, h^2=0.17) used in this paper are taken from the latest analysis incorporating data from the 2008 – 2011 shearing of the Sheep CRC IN (van der Werf *et al.* 2010) Merino yearlings (Hatcher and Preston unpublished). Scoured wool colour measurement on IN wool samples was carried out according to the standard IWTO test method (IWTO 2003). Photostability was measured using a method based on exposure to UVB (280-320nm) radiation for 4 hours (Millington and King 2010).

RESULTS AND DISCUSSION

The genetic variation in brightness, whiteness and photostability indicates that each trait will respond to selection. The high heritabilities of brightness and whiteness (0.51 and 0.33 respectively) indicate that significant progress could be made if single trait selection was undertaken. However, as the key economic traits of importance to Merino wool production are clean fleece weight (CFW), FD and staple strength (SS) (Swan *et al*. 2007) it is unlikely single trait selection for brightness, whiteness and photostability, which are essentially traits of secondary economic importance, will occur. In this context it is the predicted responses in the colour traits resulting from the use of selection indexes commonly used in the Merino industry that will determine the likely rate genetic progress under current market conditions.

Breeding objectives with a high emphasis on reducing FD generate correlated improvements in brightness over a 10 year period. However the changes are small, just 0.11 and 0.15 Tristimulus units (T units) for the Merino 7% and 14% indexes respectively (Table 1). Breeding objectives with a high emphasis on CFW will generate little correlated change in brightness with an improvement of 0.03 T units in 10 years. However, both the dual purpose breeding objectives will result in deterioration in brightness, by -0.18 and -0.06 T units respectively. Including brightness as selection criteria in the breeding objective did generate a slight improvement in brightness, though the effect was nominal just 0.01 T units across the range of indexes.

Only the Merino 14% index generated a correlated improvement in whiteness, with wool predicted to become whiter by -0.16 T units following 10 years of selection (Table 1). The other indexes would all lead to a deterioration in whiteness (i.e. an increase in yellowness) of between 0.08 (Merino 7%) to 0.48 T units (Dual Purpose 7%) after 10 years. Including whiteness as a selection criterion increased the correlated improvement in whiteness by the Merino 14% index, by just 0.03 T units, although there was little impact on the whiteness in any of the other indexes.

Table 1. Predicted responses in brightness, whiteness and photostability (Tristimulus Units) from selection over 10 years, using a) standard MERINOSELECT™ indexes and b) including brightness, whiteness and photostability as selection criteria

	Merino			Dual Purpose	
	3.5%	7%	14%	3.5%	7%
a) Brightness, whiteness and photostability <u>not included</u> in the selection criteria					
Brightness	0.03	0.11	0.15	-0.18	-0.06
Whiteness	0.35	0.08	-0.16	0.48	0.20
Photostability	-0.16	-0.11	-0.05	-0.22	-0.17
b) Brightness, whiteness and photostability <u>included</u> in the selection criteria					
Brightness	0.04	0.12	0.16	-0.17	-0.06
Whiteness	0.36	0.07	-0.19	0.50	0.20
Photostability	-0.16	-0.11	-0.04	-0.22	-0.17

Each of the indexes generated correlated improvements in photostability (i.e. reductions in photoyellowing). The correlated improvements were greatest for the dual purpose and Merino breeding objectives with a higher emphasis on CFW due to the favourable negative genetic correlation between CFW and photostability (-0.36, Hatcher and Preston unpublished), such that higher CFW is genetically associated with a reduced propensity of wool to yellow following exposure to UVB radiation. Despite this favourable genetic relationship, including photostability as a selection criterion into the breeding objective did not significantly change the predicted response after 10 years of selection (Table 1). Given that oxidative bleaching decreases photostability by 3 T units (Millington *et al.* 2013), the small correlated improvements in photostability achievable through using common Merino selection indexes are likely to be of little commercial significance.

Selection responses of between 5 to 10 T units for brightness and 5 T units for whiteness are necessary to remove the requirement for peroxide bleaching of wool during processing (Millington *et al.* 2013). The average brightness, whiteness and photostability of the Sheep CRC IN yearling progeny shorn from 2008 to 2011 was 70.0, 8.2 and 4.5 T units respectively. Based on these averages, the correlated responses in the colour traits achieved through using common Merino selection indexes would need to generate improvements of 10 to 15 T units for brightness and 4.7 to 5.2 T units for whiteness to make oxidative bleaching unnecessary. The results of this paper indicate that correlated improvements of such magnitude are not possible from commonly used Merino selection indexes. Increasing the selection emphasis applied to the colour traits in these selection indexes will elicit a greater genetic response, however, this is likely to decrease the potential gains CFW, FD and staple strength which are key drivers of profitability in Merino enterprises. However these responses were modelled on a 'typical' ram-breeding flock with no use of outside sires. Using introduced sires with significantly brighter, whiter and more photostable fleeces is an option to speed up the rate of genetic improvement. The range of estimated breeding values (EBV) of sires used in the IN was 2.8 for brightness (-1.4 to 1.4), 3.4 for whiteness (-1.8 to 1.6) and 0.9 for photostability (-0.4 to 0.5), indicating that selection of sires with brighter and whiter wool is possible for brightness and whiteness but less so for photostability due to the narrow EBV range for that trait. The issue then becomes one of identifying whiter sires in industry which is problematic given the low adoption rate of colour measurement in the Australian sheep industry (Millington *et al.* 2011) and the routine use of subjective assessment of greasy wool colour by breeders for ram selection (Brown 2006) rather than the more expensive direct objective measurement of brightness and whiteness on scoured wool. The moderate genetic correlation between greasy colour and whiteness (0.52) (Hatcher *et al*. 2011) among IN progeny indicates that greasy wool colour is a useful alternative selection criterion for whiteness, nevertheless the accuracy of identification of whiter sires may be compromised if whiteness is not directly measured given the narrow range of sire EBVs.

Genetics does play a role in controlling the brightness, whiteness and photostability of wool, as the heritability of these traits ranges from 0.17 (photostability) to 0.51 (whiteness). However many other variables including fibre diameter variation, differences in grazing environments (UV intensity, soil type, soil chemistry and ambient temperature), time of shearing, sebum production in the skin and the presence of bacteria mediate the expression of these traits (Hatcher *et al.* 2010) and may place an upper threshold on the achievable selection response. Sheep coats are an economically viable on-farm management intervention to increase whiteness, by 1 unit (Hatcher *et al.* 2003) depending on the length of time they are worn following shearing (Hatcher *et al.* 2008). As the current whitest Merino wools have whiteness of 6 T units (Millington *et al.* 2013), using sheep coats in conjunction with selection is unlikely to generate sufficient additive improvement in brightness or whiteness to make the use of routine oxidative bleaching of wool during processing unnecessary. Chemical bleaching of wool fibre during processing will remain necessary for wool to gain and maintain market share in the trans-seasonal knitwear, sports and leisurewear markets.

ACKNOWLEDGEMENTS

We acknowledge the dedicated team of scientists and technical staff at each of the 8 INF sites who are responsible for management of each of the flocks and implementation of the comprehensive sampling, assessment and measurement protocols.

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