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Staple tenacity versus staple strength

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ABSTRACT

Staple tenacity is an estimate of the peak force to break a staple of a certain cross-sectional area at the point of break. Staple strength is a measure of the peak force to break a certain weight of staple. Using the density of wool and the length of staple broken, both estimates can be converted to force per unit linear density (N/ktex). The relationship between these two estimates was examined. Midside wool samples were collected at shearing from 164 ewe hoggets from lines of New Zealand Romneys that have been selected for or against staple tenacity, and a randomly selected control line. Five staples from each sample were measured for staple strength and staple tenacity. This was accomplished by defining the cross-sectional area at the break point, breaking the staple to estimate peak force and then cutting the portion of the staple from between the jaws and determining the weight of clean wool after scouring. The High staple tenacity line had a significantly higher staple strength ($P < 0.001$) and staple tenacity ($P < 0.001$). Although a similar weight of greasy wool was removed from between the jaws for each selection line ($P = 0.336$), the weight of clean wool was significantly greater in the High staple tenacity line ($P = 0.003$). Covariate analysis revealed that the fitted relationships between staple strength and staple tenacity for the three selection lines had similar slopes ($P = 0.822$) but significantly different intercepts ($P = 0.029$). Staple strength is thus biased relative to staple tenacity in these lines, because of the differences in weight of wool between the jaws, for staples which are all the same cross-sectional area at the point of break. Staple tenacity is therefore more useful for some purposes than staple strength and vice versa, and care should be taken when drawing comparisons and conclusions and when considering which to use.

Keywords: staple tenacity; staple strength; yield; selection lines.

INTRODUCTION

Scobie *et al.,* (1994a) suggested that the term staple tenacity should be adopted to describe the tensile strength of a staple, when estimated using the cross-sectional area at the point of break to normalise the peak force to break that staple. The term staple strength is defined as the force per unit linear density to break the staple. Although cross-sectional area would usually have units of square microns or square millimetres, using the density of wool it is possible to present staple tenacity measurements in N/ktex, the same units used for staple strength.

Although the units are the same, the measurement methods are not equivalent. In fact, across a wide range of tensile strengths, the slope of the regression was 0.75 (Scobie *et al.,* 1994a), staple strength values being less than those for staple tenacity. Between breeds raised in a common environment there were notable differences in the relationship between staple strength and staple tenacity, suggesting that other wool characteristics may interact with the method of measurement (Scobie *et al.,* 1994a).

Selection lines based on staple tenacity have not only demonstrated a large separation for this characteristic, but there are also correlated responses in fibre diameter and staple length (Bray *et al.,* 1992). Differences also exist in medullation and the variability of fibre diameter (Scobie *et al.,*1994b). Despite these differences, there was no difference in the slope or intercept of the relationship between staple tenacity and staple strength between selection lines (Scobie *et al.,* 1994a). It was thus assumed that staple tenacity could be estimated from staple strength and vice verse, for Romney wool at least.

However, Scobie *et al.,* (1994a) estimated the weight of clean wool broken by correcting the greasy weight of wool between the jaws of the staple breaker using the clean wool yield of full length staples from that animal. This assumption may be invalid, since Orwin *et al.,* (1987) found that while the mean yield of the 40 mm section of the staple of Romney wool used for staple tenacity measurement was 68.4 %, that of the whole staple was considerably greater (77.5 %). Although there is no evidence for a difference in yield between the selection lines (Bray *et al.,* 1992), it is possible that the yield of separate portions of the staple may vary differentially between the selection lines.

The following experiment was designed to test whether there is a difference between selection lines in the weight of clean wool held between the jaws. A difference in the clean weight of wool actually broken would bias staple strength relative to staple tenacity, and prohibit the use of the simple conversion factor published by Scobie *et al.,* (1994a).

MATERIALS AND METHODS

Midside wool samples were collected from 164 ewe hoggets at shearing in November 1993. A subsample was removed from each and used to measure washing yield. The clean subsample was then used to estimate mean and variation of fibre diameter using an Optically based Fibre Diameter Analyser (OFDA) (BSC Electronics, 16 Doongalla Road, Attadale, 6156, Western Australia).

Staple tenacity was measured on greasy staples using a Staplebreaker (Agritest Pty Ltd, PO Box 297, Ryde, NSW), in a manner which varies from the recommended method supplied with the machine. The jaws of the Staplebreaker were set at 40 mm wide, and the staples were adjusted to the equivalent of 2 ktex at their thinnest point (Scobie *et al.*, 1994a). The section of the broken staple between the jaws was cut out and the weight of greasy wool recorded. The greasy weight was multiplied by the yield of full length staples from the midside sample to estimate the weight of clean wool between the jaws (CWT_{est}) as per the method of Scobie *et al.*, (1994a). The wool cut from between the jaws was scoured, rinsed and conditioned for determination of the actual clean weight between the jaws (CWT_{act}). Both CWT_{est} and CWT_{act} were used to estimate linear density which was then used to calculate two estimates of staple strength (SS_{est} and SS_{act} respectively). Tenacity and strength measurements were made on five staples per sheep. The relationship between staple strength and staple tenacity was compared using analysis of covariance.

RESULTS

Averages for the measurements made on full length staples are provided in Table 1. Staple length and fibre diameter were greatest in the High staple tenacity selection line ($P = 0.006$ and $P < 0.001$ respectively). Standard deviation of fibre diameter on the other hand was greatest in the Low staple tenacity line ($P = 0.058$), and application of mean fibre diameter as a covariate revealed a highly significant difference between lines ($P < 0.001$). Yield of the midside sample (Staple yield) and yield of the portion of the staple broken are also displayed in Table 1. In comparison, there was more grease in the portion actually broken, and less in the High staple tenacity line, but this difference was only significant in staple yield ($P = 0.010$).

TABLE 1: The number of ewe hoggets in each selection line, average staple length, fibre diameter (FD), standard deviation of fibre diameter (FDstdev), yield of clean wool from the midside patch (Staple yield), and yield of clean wool between the jaws for Low staple tenacity (LST), Control and High staple tenacity (HST) selection lines.

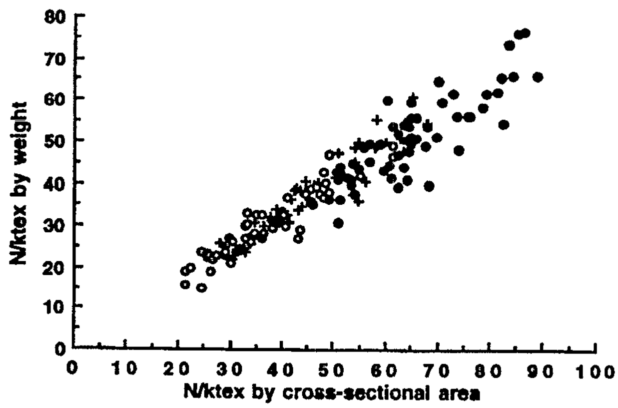
	n	Staple length mm	FD µm	FDstdev %	Staple yield %	Yield
LST	56	160	32.8	9.50	76.3	72.6
Control	45	158	35.1	9.25	76.7	72.9
HST	63	169	38.3	9.12	78.3	76.9
LSD (5%)		7	1.0	0.34	1.5	2.4
P-value		0.006	<0.001	0.058	0.010	0.091

Average weight and tensile strength measurements for the portion of wool held between the jaws of the Staplebreaker are displayed in Table 2. The average greasy weight of wool between the jaws was similar for the three selection lines ($P = 0.336$) as was CWT_{est} ($P = 0.180$). However, CWT_{act} was significantly greater in the High staple tenacity line than the other two ($P = 0.003$). Average staple tenacity and staple strength calculated using CWT_{act} (SS_{act}) for individual sheep are displayed in Figure 1. Covariate analysis revealed the fitted relationships for the three selection lines to have significantly different intercepts ($P = 0.029$) but a common slope ($P = 0.822$). In contrast, calculations of staple strength made using CWT_{est}, (SS_{est}) were approximately 2 N/ktex weaker than when using CWT_{act}. Covariate analysis then suggested that there was no significant difference in either the slope ($P = 0.594$) or intercept ($P = 0.174$) of the fitted relationships between SS_{est} and staple tenacity.

TABLE 2: Average staple tenacity, greasy weight of wool between the jaws (GWT), estimated (CWT_{est}) and measured (CWT_{act}) clean weight of wool between the jaws and staple strength estimated using CWT_{est} (SS_{est}) and CWT_{act} (SS_{act}) for Low staple tenacity (LST), Control and High staple tenacity (HST) selection lines.

	Staple tenacity N/ktex	GWT mg	CWT_{est} mg	CWT_{act} N/ktex	SS_{est} N/ktex	SS_{act}
LST	32.1	138	106	99	24.8	26.1
Control	41.0	135	105	98	32.2	33.9
HST	58.1	140	103	104	43.2	45.3
LSD (5%)	4.2	7	3	4	3.5	3.7
P-value	<0.001	0.336	0.180	0.003	<0.001	<0.001

FIGURE 1: The relationship between the tensile strength of a staple (N/ktex) measured by either cross-sectional area or by the weight of clean wool actually broken, for Romney ewe hoggets from lines selected for increased (High ●) or decreased (Low ○) staple tenacity, and a randomly selected Control line (+)



DISCUSSION

It is alarming that staple strength, or peak force to break a staple corrected for the actual weight of clean wool broken (CWT_{act}), cannot be estimated from staple tenacity in these selection lines. This is in direct contrast to the conclusions of Scobie *et al.*, (1994a), who observed differences between breeds with widely different wool characteristics but not between these selection lines. However, based on the current estimates of staple strength calculated using CWT_{est}, (SS_{est}), we would have to concur with the conclusions of Scobie *et al.*, (1994a) that there is no bias between the lines. Staple strength estimates that are calculated using greasy weight of the portion broken and average yield of the entire staple are therefore likely to be biased with respect to staple tenacity, for Romney wool at least. There were also differences in average staple length between the selection lines, and the errors of measurement would be exacerbated if staple strength were measured using the entire length of the staple rather than a constant 40 mm. For seasonal breeds of sheep such as the Romney, which exhibit large seasonal changes in diameter and yield, staple tenacity measured on a constant length of staple adjusted to a constant minimum cross-sectional area is the least biased measurement for comparing individuals.

The results presented here are not at odds with those of Vizard *et al.,* (1994), since that study used pneumatic callipers to measure cross-sectional area of the staple at the top, middle and bottom and averaged the three to estimate kilotex, which gave good agreement with staple strength estimates made on ATLAS. While this indicates that the average cross-sectional area of a greasy staple is correlated with the clean weight of that staple, both measures of strength are expected to underestimate the true tensile strength of the staple. We believe our method of measuring the tensile strength of a staple, using cross-sectional area at the point of break, is a more accurate measurement and we have chosen to differentiate it from measures based on total staple yields and weights by labelling it "staple tenacity".

Caffin jaws (Caffin, 1976) have been used to measure staple thickness. They have been calibrated, and 40 mm sections of clean rovings that weigh 80 mg, measure 2 ktex using this system. This is equivalent to the average thickness of the staple at the break-point of the staples tested. The overall mean CWT_{act} was 101 mg or 2.52 ktex, hence the 0.8 slope of the overall regression line between staple tenacity and staple strength. Using total staple yield and greasy weight between the jaws to estimate the weight of clean wool broken, Scobie *et al.,* (1994a) reported 104 mg (2.6 ktex), compared with 105 mg (CWT_{est}) for the current experiment. The slope of the overall regression line between staple tenacity and staple strength estimated in this way, using the current data (SS_{est}), was 0.77, closer to that of Scobie *et al.,* (1994a). Seasonal changes in the rate of wool growth must be responsible for this discrepancy, and on average a staple which is 2 ktex at the point at which it breaks, is flanked by 20 mm long regions that are 2.5 ktex on average.

The evidence presented here for selection lines suggests that the discrepancies between breeds found by Scobie *et al.,* (1994a), and attributed to diameter and medullation, should be re-examined using the amount of clean wool broken. On the other hand, staple tenacity could be expected to be in error when measuring medullated wools, because the cross-sectional area will over-estimate the actual area of fibre keratin which is broken. Since Romney wool is generally not medullated in the winter (Scobie *et al.,* 1993), staple tenacity should not be adversely affected relative to staple strength by this characteristic.

The effects of fibre diameter and fibre diameter variability on both techniques requires further investigation to resolve any bias which this may introduce. As Scobie *et al.,* (1994b) found, the current series of samples from the Low staple tenacity line were lower in average fibre diameter ($P < 0.001$) but on average had a higher mean standard deviation of fibre diameter relative to the High and Control selection lines ($P < 0.001$, by covariate analysis) and relative to that found in wool of the same fibre diameter (Edmunds 1993).

Above all, it is critical to specify the exact conditions of measurement. Since the two measures are distinct, it may be appropriate to consider the use of separate units. Staple strength is an estimate of the tensile strength of a staple per unit linear density, however, staple tenacity estimates the tensile strength of the weakest point in that staple and force per unit cross-sectional area may be the appropriate unit. Using the density of wool, a staple one kilotex at the point of break would have a cross-sectional area of 0.762 mm^2 at that point. The Control line wools in this study for example, would have a staple tenacity of 53.8 N/mm^2 (41 N/ktex divided by 0.762 mm^2). Staple tenacity and staple strength are not interconvertible and in some cases, staple tenacity will be the most appropriate whereas others may lend themselves to staple strength. As a selection criterion, staple tenacity will be more useful since it compares the strength of wool grown during a critical time period and is not biased by the characteristics of the staple at other points in time. Which one is most useful for predicting processing performance is yet to be established.

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