Prediction of Cashmere Style Using Objective Fiber Measurements[1,2]

C.J. Lupton[3,4], F.A. Pfeiffer[3], and A.R. Dooling[5]

Summary

Multiple objective fleece and fiber measurements were made on 25 raw cashmere samples (5 of each style score [1-5] from cashmere goats) to establish mathematical relationships between the objectively determined characteristics and cashmere style score (CSS) subjectively assessed by an expert cashmere classer. Measurements included cashmere down yield (DY), average fiber diameter (AFD), guard hair and down staple lengths (GHSL and DSL), and average fiber curvature (AFC) of 2 mm snippets. The AFD and AFC were measured concurrently using an Optical Fibre Diameter Analyser. Cashmere style score was significantly correlated (in increasing order) with DSL, GHSL, AFD, and AFC. A second set of 25 raw cashmere samples was measured in the same manner and AFC was used to predict CSS. For actual versus predicted CSS, $r^2 = .63$ with a standard error of prediction (SEP) = 1 (cashmere style score units). Discriminant analysis confirmed that predicted CSS would invariably be within ± 1 unit of actual CSS.

Fiber curvature was shown to be the best single objectively measured trait for predicting cashmere style score. It should provide a useful, inexpensive, and potentially more accurate and consistent alternative for assessing this important trait.

Key words: Cashmere, style, fiber curvature, objective fiber measurements.

Introduction

Cashmere style is an ill-defined but important characteristic of raw cashmere. Early attempts to define style invariably resulted in some objections from one segment of the industry or another. A definition of "good style" that has received some degree of acceptance in the U.S. is as follows: cashmere of good style has irregular crimp of relatively small magnitude and high frequency that does not lie in two dimensions but rather changes directions at irregular intervals along the length of individual fibers (Lupton, 1991). Straight fibers or those containing bold (mohair-like) or two-dimensional (like some fine wools) crimp are considered to have poor style. In an attempt to better describe the spectrum of cashmere styles currently being produced by goats in the U.S., a numerical scoring system was devised (by A.R. Dooling) that is being used in conjunction with subjective assessment.

Cashmere style is considered to be important by processors for several reasons: first, it distinguishes cashmere from other fine fibers; secondly, it affects the efficiency of the dehairing process and other mechanical processes up to spinning; and thirdly, it affects the hand (feel) of the finished fabric. Since cashmere goats were introduced into the U.S. in 1989, assessment of cashmere style has also been influenced (to varying degrees) by amount of luster in the down fibers, fleece color, down yield, average fiber diameter, and length of guard hair and down fibers. Intensive training is required for developing the ability to consistently and accurately assess style. Regular practice using fleeces of established style scores is necessary for the classer to retain the acquired skill. There has been a need to develop a method for objectively measuring cashmere style.

Recently, the manufacturer of the Optical Fibre Diameter Analyser (OFDA; Baxter et al., 1992) introduced a program for measuring snippet (a short fiber ~ 2mm in length) curvature (degrees/mm). This program has been used to measure curvature of wool snippets, a characteristic that has been shown to be highly correlated with fiber crimp and bulk (Edmunds and Sumner, 1996). The objective of this study was to compare objectively measured fiber curvature and other fiber and fleece characteristics to subjectively assessed cashmere style.

[1] This article reports research conducted by the Texas Agricultural Experiment Station, The Texas A&M University System.

[2] Financial support from the Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture under agreement number 95-34148-1326 is gratefully acknowledged.

[3] Texas Agricultural Experiment Station, 7887 U.S. Highway 87 N., San Angelo, TX 76901-9714.

[4] To whom reprint requests should be addressed.

[5] Pioneer Mountain Farm, Dillon, MT 59725.

Materials and Methods

A set of cashmere fleece samples (25) representing the broad spectrum of cashmere style scores (CSS; 1-5) was obtained from a U.S. cashmere buyer/ manufacturer (Montana Knits, Inc., Dillon, MT). Cashmere style score was assessed for each sample by an expert cashmere classer. A score of 1 signified excellent style whereas a score of 5 meant poor style. Subsamples were removed from each raw cashmere sample and used to determine straightened down and guard hair staple lengths (DSL and GHSL, respectively) using a standard method of the American Society for Testing and Materials (ASTM, 1997). Subsequently, the remainder of each sample was dehaired using a Shirley Analyzer (International Wool Textile Organisation [IWTO], 1992) and the resulting separated down was quantified in terms of average fiber diameter (AFD; IWTO, 1995) and average fiber curvature (AFC; IWTO, 1997) using an OFDA. After separation, the guard hair and down portions from each sample were individually weighed, thus permitting calculation of cashmere down yield (DY). Stepwise multiple linear regression analysis was used to establish a linear relationship between dependant variable CSS and the objectively measured characteristics. In addition, correlation analysis was used to establish the linear relationships among all characteristics assessed, measured, and derived. A second set of 25 raw cashmere samples was then measured in the same manner as the first and AFC was used to predict CSS using the previously established regression equation. Next, simple linear regression analysis was used to examine the relationship between predicted and actual CSS. Finally, discriminant analysis was used to classify each sample of the second set in terms of CSS. All statistical analyses were conducted using the CORR, DISCRIM, MEANS, and REG procedures of SAS (SAS, 1996).

Results and Discussion

The simple statistics for variables estimated, measured, and derived from the two sets of raw cashmere samples are summarized in Tables 1 and 2. Mean values of each variable in the two sets were not different ($P > .05$) even though arithmetically, the first set of samples was slightly coarser (down AFD) and higher yielding than the second set. Stepwise multiple linear regression analysis of the first data set for dependant variable CSS resulted in only AFC and SD of AFC entering the model for $P < .1$ (producing an $r^2 = .64$. This occurred despite the significant correlations shown in Table 3 between CSS and down staple length, guard hair staple length, and down average fiber diameter, but not down yield). For this set of samples, CSS is obviously related to several other variables but most highly and significantly to average fiber curvature. The equation relating CSS, AFC, and SD of FC is:

$$CSS = 6.33 - .15 \times AFC + .10 \times SD\ of\ AFC.$$

After the second set of raw cashmere samples was objectively measured, the above equation was used to predict CSS. When predicted CSS were regressed against actual CSS values, an r^2 value =

Table 1. Simple statistics for variables estimated, measured, and derived on the first set of raw cashmere samples.

Variable	Mean	SD	Minimum	Maximum
Cashmere style score, 1-5	3.0	1.4	1.0	5.0
Down staple length, in	2.9	.8	1.6	4.8
SD of down staple length, in	.4	.2	.1	.8
Guard hair staple length, in	3.1	1.3	1.7	5.9
SD of guard hair staple length, in	.6	.4	.2	1.8
Down average fiber diameter, µm	18.2	2.5	14.7	24.5
SD of down fiber diameter, µm	4.1	.8	2.9	6.5
Average fiber curvature, degrees/mm	59.4	11.3	35.6	80.2
SD of fiber curvature, degrees/mm	51.7	6.9	35.0	67.0
Down yield, %	54.5	18.5	18.8	91.5

.63 was obtained with a SEP = 1 (CSS). Next, data generated using all 50 raw cashmere samples were analyzed by the stepwise multiple regression procedure for dependant variable CSS. This time GHSL entered the equation in step 2, in addition to AFC (step 1) and SD of AFC (step 3), to produce the following equation:

$$CSS = 6.90 - .26 \times GHSL - .12 \times AFC + .08 \times SD\ of\ AFC,$$ having an $r^2 = .70$.

No other variables entered the equation below the $P < .3$ level. To further evaluate the accuracy of predicting classification variable CSS using objectively measured data, the DISCRIM procedure of SAS was used to derive a linear discriminant function for CSS using the qualitative variables AFC, GHSL, and SDAFC of the first data set (the calibration data set). Subsequently, this discriminant function was used to classify each sample of the second set in terms of CSS. The results of this analysis are summarized in Tables 4 and 5. For the test data, only one predicted CSS value was more than one CSS unit greater than the actual value (a sample scored as a 5 was predicted to be at 3). All other predictions were within ± 1 CSS unit (as expected from the SEP calculated from the earlier regression analysis). The error rates (probabilities of misclassification) in the classification of future observations were .40 and .36 for the calibration and test data, respectively.

Correlation analyses for CSS versus all the other variables were conducted on the combined sets of 50 samples, and showed that CSS is significantly correlated with GHSL ($r = -.48$, $P = .0004$), AFD ($r = .37$, $P = .008$), SD of AFD ($r = .48$, $P = .0004$), AFC ($r = -.77$, $P = .0001$) and SD of AFC ($r = -.51$, $P = .0002$). In other words, better cashmere style scores (i.e., lower numbers) are associated with longer guard hair and finer, more uniform (in terms of AFD) down having higher fiber curvature values (i.e., more crimp). This conclusion would tend to confirm the "conventional wisdom" of most cashmere breeders. These data indicate that cashmere style is not associated with yield ($P = .11$).

Conclusions

This preliminary study indicates that average fiber curvature as measured by the Optical Fibre Diameter Analyser is significantly correlated with subjectively assessed cashmere style score. Further work is required to validate this conclusion for other cashmere classers and for a greater distribution of cashmere samples. The repeatability of individual subjective appraisers and variability among classers should also be established.

Implications

If the significant relationship between cashmere style score and fiber curvature holds true for other cashmere classers, then we will have discovered a simple, objective, potentially inexpensive, and likely a more consistent way to estimate

Table 2. Simple statistics for variables estimated, measured, and derived on the second set of raw cashmere samples.

Variable	Mean	SD	Minimum	Maximum
Cashmere style score, 1-5	3.1	1.4	1.0	5.0
Down staple length, in	3.1	.8	1.8	4.9
SD of down staple length, in	.3	.2	.1	1.2
Guard hair staple length, in	3.1	1.2	1.4	5.7
SD of guard hair staple length, in	.7	.5	.1	1.8
Down average fiber diameter, μm	17.0	1.7	14.7	20.6
SD of down fiber diameter, μm	3.7	.6	2.9	5.1
Average fiber curvature, degrees/mm	57.9	11.7	34.5	78.4
SD of fiber curvature, degrees/mm	52.6	6.7	39.0	68.0
Down yield, %	52.6	13.8	36.3	90.9

cashmere style score. The AFC measurement should be inexpensive because it can be obtained concurrently with the down AFD measurement using the OFDA while incurring no extra cost. Such a measurement would be very useful to the many cashmere breeders who have not undergone the intensive training required to become a cashmere classer or who have undergone the training but failed to develop or maintain the necessary skill.

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Table 3. Correlation coefficients and probability values for the linear relationships between cashmere style score (CSS) and the listed variables (first data set).

Variable	Correlation coefficient, r	Probability
Down staple length	.42	.04
SD of down staple length	-.04	.85
Guard hair staple length	-.42	.04
SD of guard hair staple length	-.03	.87
Down average fiber diameter	.53	.006
SD of down average fiber diameter	.60	.002
Average fiber curvature	-.74	.0001
SD of fiber curvature	-.42	.04
Down yield	.23	.27