Wool fibre diameter effects on yarn bulk independent of core bulk

D.C. MADDEVER AND A. BRAY[1]

WRONZ, Private Bag 4749, Christchurch, New Zealand.

ABSTRACT

The curvature and diameter of fibres influence the core bulk of raw wool, which in turn is used as an indicator of yarn bulk. The compressional properties of fibre masses are difficult to predict from first principles, therefore the direct effect of fibre diameter and curvature on the bulk of semi-worsted yarn was investigated. Wools with similar core bulk (28 cm^3/g) in which fibre diameter ranged from 18.5 to 40 µm were processed into semi-worsted yarn and measured for yarn bulk.

Contrary to popular belief, fine wool of the same core bulk produced yarn with higher bulk than stronger wool. However, with a correlation coefficient of -0.9 between mean fibre diameter and mean fibre curvature the influence of these two attributes on yarn bulk cannot be separated. Closer examination of the data shows that for these wools, which were selected to have constant core bulk, the variation in yarn bulk can be predicted slightly more accurately by the variation in mean diameter than the variation in mean fibre curvature between the samples.

Rather low R^2 values and the size of the coefficients in the regression equations indicate that the influence either fibre diameter or fibre curvature has on yarn bulk at 28 cm^3/g core bulk is small. Wool type also had little effect on the relationship between core bulk and yarn bulk at this level of core bulk.

Keywords: diameter; curvature; OFDA; bulk; semi-worsted yarn bulk.

INTRODUCTION

There has been a 35% reduction in the number of Perendale sheep in New Zealand from 1989 to 1996 (Wools of New Zealand, 1997) and there is an increasing amount of crossbreeding that influences fibre characteristics. This makes interpretation of the implications of fibre diameter on the space filling capacity of wool important.

Two space filling capacity measurements are in common use in New Zealand. The core bulk test (NZS 8716) has removed most of the operator bias and is now used in place of the old loose wool bulk test (WRONZ method). Yarn bulk (WRONZ channel method) is determined by compressing a quantity of yarn in a channel and measuring the volume to weight ratio. Both tests are commercially significant for a 1-2 cm^3/g change (Carnaby *et al*., 1984).

Manufacturers desire high bulk wools, especially for semi-worsted yarn, but the premiums paid for this attribute are highly variable (Maddever, 1994) and will need to be considerably higher for growers to elevate bulk above fleece weight as an animal selection criterion (Wickham and McPherson, 1985; Sumner and Hawker, 1986). This premium variability is exacerbated by a number of perceptions in the wool trade concerning the effect of fibre type on the development of bulk in wool products, particularly yarn. While core bulk is a good predictor of yarn bulk (Carnaby *et al*., 1984), it is also widely believed that for a given level of core bulk, an increase in fibre diameter and/or medullation and/or helical crimp can produce more bulky yarns, and lambs wool will give lower bulk yarns.

Intuitively it is the fibre diameter profile, flexual and torsional rigidity, fibre curvature and the arrangement of fibres in the yarn that must ultimately determine yarn bulk. Theory developed over 50 years ago by van Wyk (1946) suggests that the fibre packing density, which is influenced by both crimp and diameter, determines the compressional properties of a fibre mass. However, in the more ordered form of a yarn, approximately 50% of the crimp has been removed (Mahmoudi and Dobb, 1996), which might point to fibre diameter having a greater effect. Given that for a mass of similar length fibres there will be more fibres in a fine wool (low diameter) blend, the independent effect of fibre diameter on yarn bulk is difficult to predict. However, current use of the OFDA and Laserscan fibre diameter measuring equipment also allows the measurement of fibre curvature (Edmunds, 1997) which gives useful parameters to assist in predicting the resulting core or yarn bulk from loose wool fibre attributes.

When selecting wool for semi-worsted compared to woollen yarn constructions, manufacturers face a problem in that the longer wools required for the former process, tend to be high diameter, low curvature and hence lower in bulk, reducing the achievable level of yarn bulk. Thus, for most semi-worsted yarn manufacture, because bulk is important, sourcing of suitable blend components can be difficult.

The purpose of this trial was to look at the fibre attributes that determine the bulk of semi-worsted yarn, given a particular constant level of core bulk. Wools with a range of mean fibre diameters were selected to have a relatively high core bulk and processed into semi-worsted yarn to compare the yarn bulk levels achieved.

[1] AgResearch P.O. Box 60 Lincoln, New Zealand

METHOD

Fibre selected from wool auction samples and WRONZ stock were sampled and tested in the scoured loose wool state, then processed in the WRONZ pilot plant into nominally R400/4 tex semi-worsted yarn with 170 tpm Z twist in the singles and 100 tpm S plyed twist. An initial set of 11 samples, ranging from 29 to 40 µm, produced an interesting trend, but inconclusive results, so a further 13 blends were selected to validate the trend by extending the range of fibre diameters down to 18.5 µm. Helical crimped wool from DownX type, supposedly soft lambs wool and harsh crutchings, can all be relatively short so each was blended with longer wool to achieve satisfactory blends suitable for semi-worsted processing. One lot chosen from WRONZ stock in the first trial was duplicated in the second trial. Also, since the second part of the trial involved fine wool that required a different finer carding machine, a duplicate for comparing the results from the fine and coarse wool cards was included.

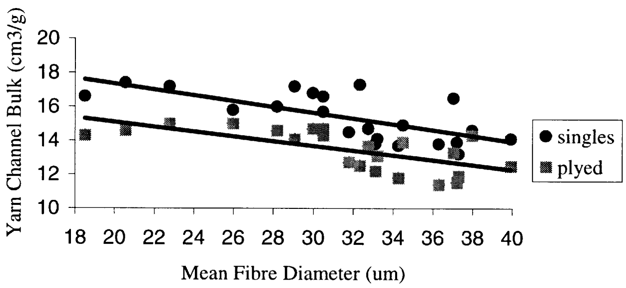
Extensive fibre attribute testing, including OFDA mean fibre diameter and curvature, was carried out and both singles and plyed yarn bulk were measured on the steam relaxed yarns using a channel bulkometer (Carnaby *et al*., 1984). The consistency of the singles yarns was checked through a series of standard yarn tests.

RESULTS

Linear regression models in Figure 1 show the effect of mean fibre diameter on yarn bulk. Selected test results of 22 lots processed into yarn in the two parts of the trial are presented in Table 1. Two further lots were omitted from the results: the finest wool selected for the trial proved to be too short for semi-worsted processing and the quantity available of wool with the highest sample core bulk result was insufficient to complete the trial. Core bulk was checked and OFDA parameters were used to predict projection microscope medullation (A.R.Edmunds, pers com). Correlations between these attributes are given in Table 2.

Channel yarn bulk test results are variable and thus are an average of four samples. In this trial the average standard error of the singles yarn bulk results was 0.3 cm^3/g and that of the plyed yarn 0.2 cm^3/g.

FIGURE 1: Yarn bulk versus mean fibre diameter



Regression equations:

singles yarn bulk = -0.17 * diam + 20.8 R^2 = 45%
(SE = 0.04) (SE = 1.3)

plyed yarn bulk = -0.14 * diam + 17.9 R^2 = 41%
(SE = 0.04) (SE = 1.1)

TABLE 1: Wool fibre and yarn bulk properties

Description breed/blend	Core bulk (cm^3/g)	OFDA diameter (µm)	OFDA medulla (% by wt)	OFDA curvature (deg./mm)	Yarn bulk Plyed (cm^3/g)	Yarn bulk Singles (cm^3/g)
Halfbred fine card	26.8	30.5	0.8	69.8	14.7	16.6
Halfbred coarse card	26.9	30.5	0.8	69.8	14.3	15.7
Halfbred	27.1	30.0	0.5	69.9	14.7	16.8
Merino	26.7	18.5	0.1	99.5	14.3	16.6
Merino lambs/fleece	27.5	26.0	0.7	79.3	15.0	15.8
Xbd crutch/Perendale	28.0	38.0	3.6	55.1	14.3	14.6
Merino	26.4	20.6	0.2	97.8	14.6	17.4
DownX/Crossbred	26.7	34.5	2.2	60.4	13.9	14.9
Merino/Merino	27.4	22.8	0.4	89.3	15.0	17.2
Perendale/Merino	27.5	28.2	0.6	71.5	14.6	16.0
Drysdale/Perendale	27.0	37.3	17.5	60.8	11.9	13.2
Crossbred duplicate	24.4	33.2	1.1	52.5	13.1	14.1
Crossbred duplicate*	26.0	33.1	1.1	65.4	12.2	13.8
Perendale Hogget*	30.0	32.3	5.6	70.4	12.5	17.3
Perendale*	29.0	36.3	3.8	64.9	11.4	13.8
Perendale Hogget*	30.0	32.8	3.4	68.9	13.7	14.7
Perendale*	31.0	37.0	6.2	65.9	13.3	16.5
Perendale*	29.0	37.2	2.5	61.5	11.5	13.9
Perendale*	31.0	39.9	10.8	61.3	12.5	14.1
Ryeland/Crossbred*	29.0	34.3	2.7	75.2	11.8	13.7
Xbd crutch/Crossbred*	29.0	31.8	2.0	74.9	12.7	14.5
Corredale*	30.0	29.1	0.8	80.5	14.1	17.2

* lots in the first part of the trial

TABLE 2: Correlations between fibre and yarn bulk properties

	Fibre properties diameter	medulla	curvature	Yarn bulk - singles
medulla	0.60			
curvature	-0.90	-0.42		
yarn bulk - singles	-0.69	-0.45	0.64	
yarn bulk - plyed	-0.66	-0.52	0.45	0.73

DISCUSSION

Fibre selection for constant core bulk in the first part of the trial was based on imprecise core bulk assessments that gave rather high and variable values for the core bulk of the samples taken. However, the low correlations between core bulk and the properties of fibre curvature and yarn bulk are an indication that much of this variability is likely to be due to sampling and measurement errors.

Mean fibre diameter and curvature in this set of wools have a high correlation coefficient of -0.90. This very strong relationship prevents the determination of the separate effects of these two attributes on yarn bulk.

The test results of the crossbred lot used to check the repeatability of the trial unfortunately indicated that the curvature, and hence core bulk, had either been lost in storage or was a random aberration. However, the resulting yarn properties, including both channel bulk results, were not significantly different. Halfbred wool processed on both the fine and coarse card produced quite variable yarns for some unknown reason, but they were not significantly different from each other for yarn bulk.

It might be expected that a greater contribution to bulk would come from diameter in the relatively ordered state of the yarn bulk test compared to the more random assembly of fibres in the core bulk test. However, the results produced no strong evidence of this (Figure 1), possibly due to the extra fibres in the finer wool/yarn sample and the extra curvature and increased internal stresses in yarns made from fine fibres.

Across breeds diameter is negatively correlated with bulk (Elliott, 1986) but within a breed it can be highly variable, with some studies showing the opposite trend (eg, Kurdo, 1985). The bilateral nature of fibres creates fibre curvature that clearly is a major contributor to the compressional properties of a fibre mass. An increase in mean fibre diameter and the associated decrease in fibre curvature in this trial produced a slight decrease in the bulk achieved in semi-worsted yarn. Various factors indicate that the trend observed here is real. These are: negative coefficients in the yarn bulk prediction equations, similar equations within the two parts of the trial and the fact that the core bulk of the finer wools in the second part was on average 2.7 units lower than that of the stronger wools of the first part. Misconceptions concerning the effects different wool types have on manufacturing performance should be cleared up and clearer price signals back to the grower should be produced by a shift to using a combination of fibre curvature and other accurately measureable fibre properties to predict core bulk.

Even though medullated fibres would be expected to give greater yarn bulk because of their effectively hollow nature (Carnaby and Elliott, 1980), in this trial the more highly medullated lots, including the blends containing Drysdale wool and crutchings, seemed to have slightly lower yarn bulk results than would be expected. This could possibly reflect relatively low fibre curvature values for their diameter in medullated wools.

There were two lots blended to include helical crimp wool (DownX) and lambs wool and neither of these produced outliers in the yarn bulk data. These blends and all other blends in the trial performed in a manner that showed no effect on yarn bulk over and above that “expected” by the measured fibre attributes.

While the yarns produced in this trial all had very similar yarn bulk given the wide range of mean fibre diameters, there was a wide range of subjective feel in terms of softness, smoothness, stiffness, fullness and crispness.

CONCLUSIONS

The extra curvature and number of fibres in the cross-section of a yarn made from fine wool sheep breeds produce higher bulk semi-worsted yarns than would be expected from the bulk of the loose wool at a relatively high level of core bulk. From this trial, for semi-worsted yarn bulk it appears approximately a 6 µm mean fibre diameter reduction has the same effect on yarn bulk as raising the core bulk by 1 unit.

Fibre diameter across a wide range had a relatively minor influence on yarn bulk. An appreciation that factors other than those represented by core bulk have little effect on yarn bulk should lead to greater premiums for wool with high core bulk. This is necessary to induce wool-growers to pay more attention to wool bulk when selecting sheep.

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