Introduction to Yarnspec

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Yarnspec can be used as a quality control tool because it has the ability to predict for your actual conditions rather than generalities. Yarnspec takes into account the fibre properties of the top and your spinning parameters to predict yarn quality and spinning performance. The Uster Statistics are based on the statistical analysis of various yarn qualities world wide. This provides a quality benchmark for your yarns.

Introduction

The spinner demands that a top meet what can be a long list of technical specifications as well as a price. These are designed to ensure the top will perform as expected in the spinning mill and also downstream in weaving, knitting and fabric making. Some top attributes, such as quality of scouring and combing, and suitable lubricant and anti-static agents, are difficult to determine from measurements of the top. Therefore, mills will usually liaise closely with a few selected suppliers who reliably supply to the mill's requirements. A few attributes such as dark fibre and contaminant levels can affect the suitability of the top downstream of spinning, although they do not directly impact on spinning performance. Finally, there are the fibre properties, particularly diameter and length, which are so important to spinning performance that allowed limits are chosen according to the yarn being spun.

Spinning performance and subsequent yarn performance are critical because both spinning and weaving typically cost three to four times as much as all of topmaking. Yarn breaks are so expensive in terms of labour cost and lost productivity that it is common for less than one break every 40 kilometres to be allowed (1). For a fine yarn being produced at one kilometre per hour per spindle (1 km/hr/spindle) this equates to a maximum of 50 ends-down per thousand spindle hours.

To improve the predictability of wool processing performance CSIRO has introduced a yarn and spinning prediction program, Sirolan-Yarnspec. The program aims to predict what a good modern mill can expect to achieve using a particular wool top for a given yarn under specified spinning conditions. This is a powerful and necessary tool for a closed quality control system that enables ongoing improvement and reduces error margins on cost and performance.

Sirolan-Yarnspec incorporates theory and algorithms derived from fits to experimental data. However, theory shows that all mills run up against the same limits so that expected yarn properties can be predicted without the need for a mill-dependent correction factor (once measurement systems are uniformly calibrated).

Currently, Yarnspec only applies to pure wool worsted yarns. It was originally developed for ecru weaving yarns and for these it has been most extensively validated. However, it is designed to handle the full range of dyed and un-dyed worsted knitting and weaving yarns. It is known to have problems with, for example, shrink proofed wools because they may have been subjected to different levels of chlorination and different amounts of polymer, both of which affect yarn strength. Yarnspec is now entering a phase of commercial mill validation in conjunction with Sirolan-Tensor (2), an instrument for improved measurement of fibre strength of tops.

The role of Yarnspec

Yarnspec is based on the premise that 'best commercial practice', in terms of spinning performance and yarn quality is indeed predictable. It assumes that the wool top has been scoured and combed to appropriate standards and seeks to quantify the effect of wool fibre properties of the top on spinning performance. For a good spinner who always processes identical lots it may therefore have limited relevance. However, for one less skilled in the art or with more varied tops and yarns, it can answer several questions, for example:

- Is this particular top suitable for this yarn?
- Is the quality of this yarn as expected?

It thus enables a mill to benchmark its performance. (There are no mill-dependent correction factors in Yarnspec). Possible areas for mill improvement can be identified and the quality control circle can be completed.

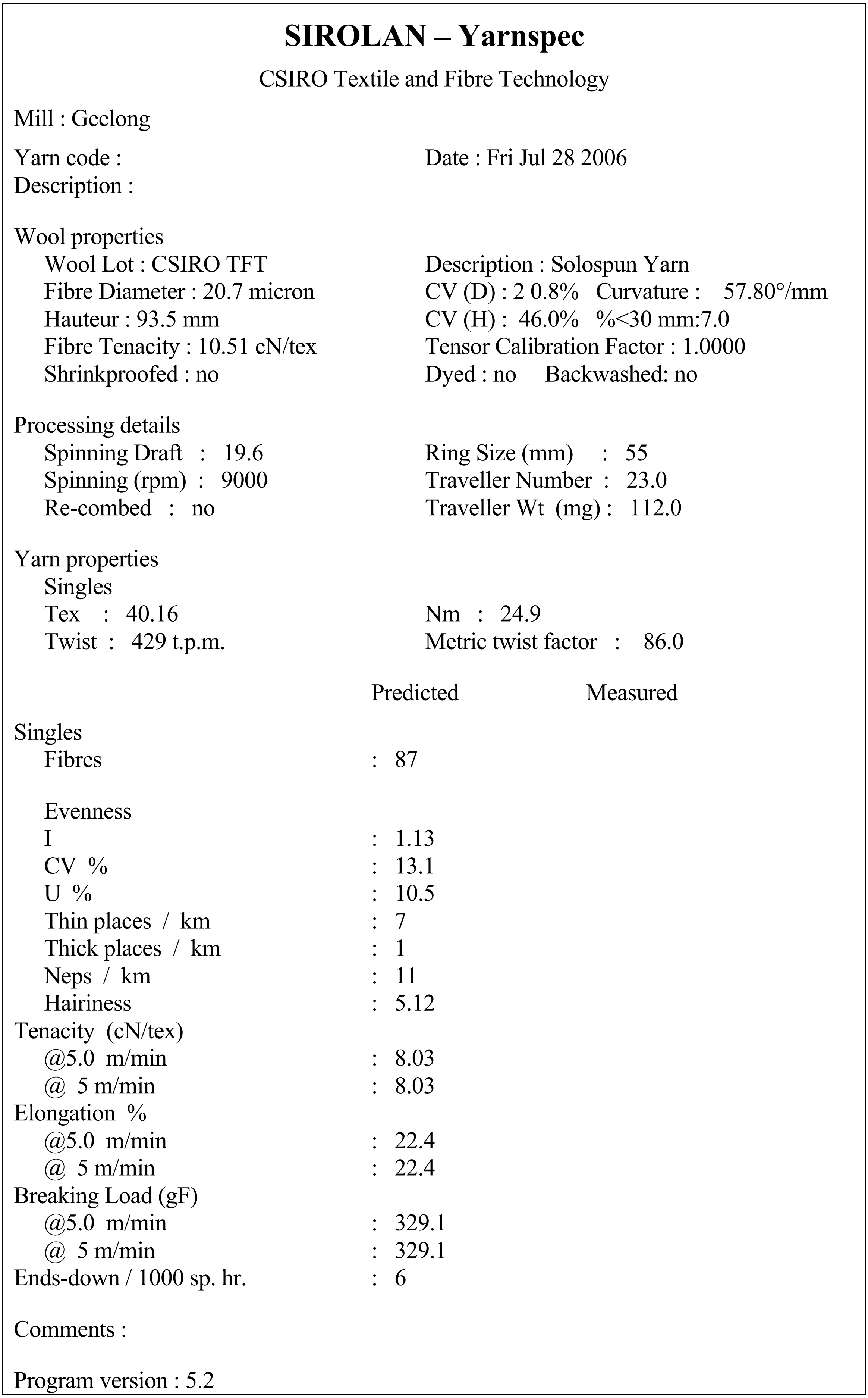
Yarnspec also enables the effect of different fibre properties to be explored so that one property can be traded off against another; for example, diameter against Hauteur. In this way a mill can explore whether different top specifications may meet its needs at a cheaper price. In this respect, the following are some of the key messages of Yarnspec:

- Mean diameter is overwhelmingly the most important top fibre property, as is already reflected in the price differentials and mill specifications.
- Mean fibre length is the next most important and 10 mm of Hauteur can be traded off against 1 μm in mean diameter in terms of its effect on yarn tenacity and ends-down in spinning. As will be discussed, this had led us to question whether long tops are undervalued. For evenness, about 25 mm trades off against 1 μm. Neither trade-off applies to fabric handle because fibre diameter, rather than tenacity and evenness, affects stiffness and softness.
- The importance of fibre length distribution CV_H, on yarn properties and spinning performance, is over-rated.
- The importance of diameter distribution CV_D is as expected, with approximately. 5% in CV_D trading-off against 1 μm.
- Fibre strength is possibly the third most important factor, but a better knowledge of how widely it varies in consignments is needed.

These messages are not meant to imply that, for particular end-uses other attributes such as dark fibre, contaminants, colour and even neps are unimportant but, in general, they do not directly affect spinning performance.

Predictions

The above know-how has been incorporated into a series of prediction algorithms within a user-friendly computer program (Sirolan-Yarnspec). The algorithms are being further refined in light of experience in our mill, and industrial validation trials are now beginning. The degree of accuracy depends not only on the quality of the algorithms but on the measurement accuracy, particularly in terms of reproducibility between different test instruments, and sufficient sampling. An example of the program print-out is shown in Figure 1.



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                         SIROLAN – Yarnspec
                  CSIRO Textile and Fibre Technology
Mill : Geelong

Yarn code :                         Date : Fri Jul 28 2006
Description :

Wool properties
   Wool Lot : CSIRO TFT             Description : Solospun Yarn
   Fibre Diameter : 20.7 micron     CV (D) : 2 0.8%   Curvature :   57.80°/mm
   Hauteur : 93.5 mm                CV (H) :  46.0%   %<30 mm:7.0
   Fibre Tenacity : 10.51 cN/tex    Tensor Calibration Factor : 1.0000
   Shrinkproofed : no               Dyed : no    Backwashed: no

Processing details
   Spinning Draft   :   19.6        Ring Size (mm)     :   55
   Spinning (rpm)  :   9000         Traveller Number  :   23.0
   Re-combed   :   no               Traveller Wt  (mg) :   112.0

Yarn properties
   Singles
   Tex    :   40.16                 Nm   :   24.9
   Twist  :   429 t.p.m.            Metric twist factor   :    86.0

                               Predicted              Measured

Singles
   Fibres                      :   87

   Evenness
   I                           :   1.13
   CV  %                       :   13.1
   U  %                        :   10.5
   Thin places  /  km          :   7
   Thick places  /  km         :   1
   Neps  /  km                 :   11
   Hairiness                   :   5.12
Tenacity  (cN/tex)
   @5.0  m/min                 :   8.03
   @  5 m/min                  :   8.03
Elongation  %
   @5.0  m/min                 :   22.4
   @  5 m/min                  :   22.4
Breaking Load (gF)
   @5.0  m/min                 :   329.1
   @  5 m/min                  :   329.1
Ends-down / 1000 sp. hr.       :   6

Comments :

Program version : 5.2
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Figure 1: Example of print-out from prediction program.

The program provides an interface for the entry of data on top properties of one or several wools, the yarn parameters and the processing conditions. The yarn evenness and the thin and thick places, as measured by the evenness tester, the yarn tenacity and elongation at two test speeds and the ends-down in spinning are predicted. The two-fold yarn evenness and strength properties are also predicted. Neps are not yet predicted. They appear to depend markedly on the quality and number of combings and the proper application of both lubricant and anti-static agent.

A plot of predicted versus measured yarn evenness for a range of wools that varied in diameter from 17.8 to 25.5 µm, in Hauteur from 56 to 96 mm, and in CV_D from 16 to 27%, is shown in Figure 2. The predicted versus measured yarn tenacity for wools whose bundle strength has been measured using the improved instrument and method (2) are shown in Figure 3. However, the yarns all had approximately the same metric twist factor (α = 90) and none were dyed or shrink proofed.

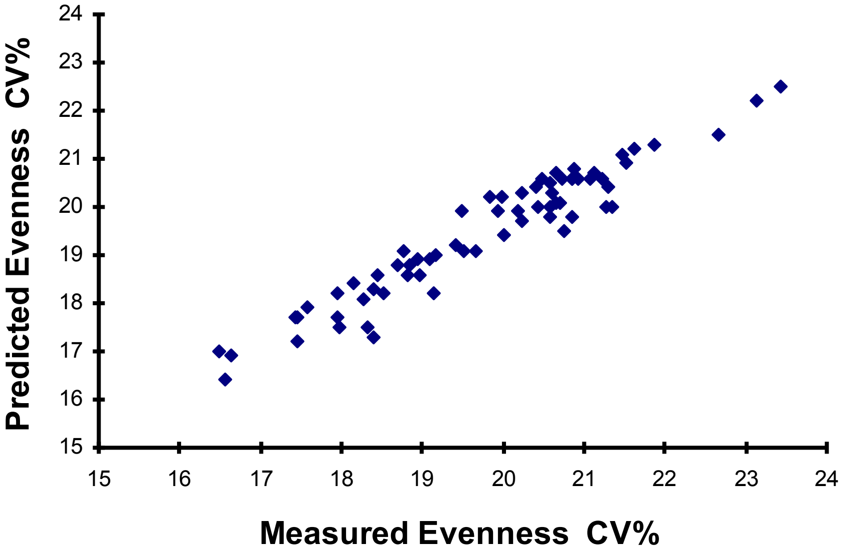

Figure 2: Predicted versus measured yarn evenness.

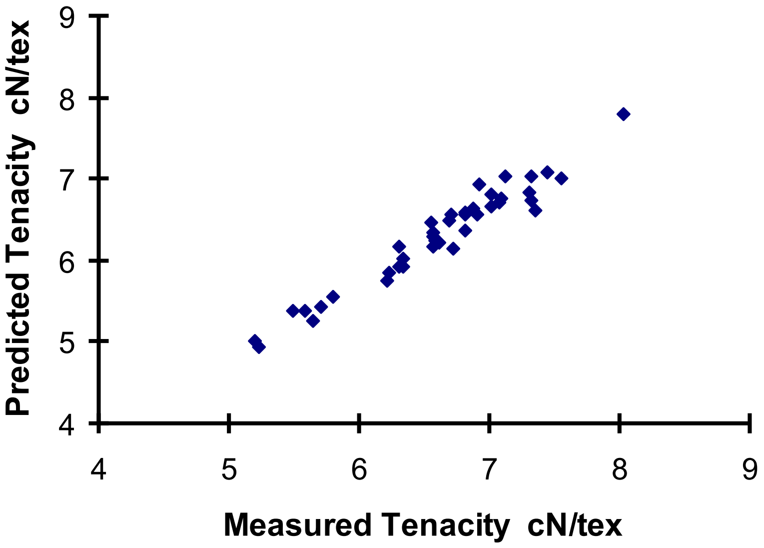

Figure 3: Predicted versus measured yarn tenacity.

The predicted versus measured ends-down for all available lots processed through the CSIRO mill, on two different spinning frames, are shown in Figure 4. The agreement is not perfect, but encouraging. We now need more extensive data from commercial mills to test the limitations of the predictions and to give mills confidence that our messages on the relative importance of fibre properties are correct.

To illustrate the trade-offs evident in our data, some of the Yarnspec (Version 2.30) predictions for yarn evenness and ends-down are presented below. The exact trade-off will vary according to the actual yarn and spinning conditions and other fibre properties, but the examples used are fairly representative for a medium to fine weaving yarn. The yarn evenness (CV%) and ends-down in spinning of such a yarn are shown as a function of fibre diameter in Table 1.

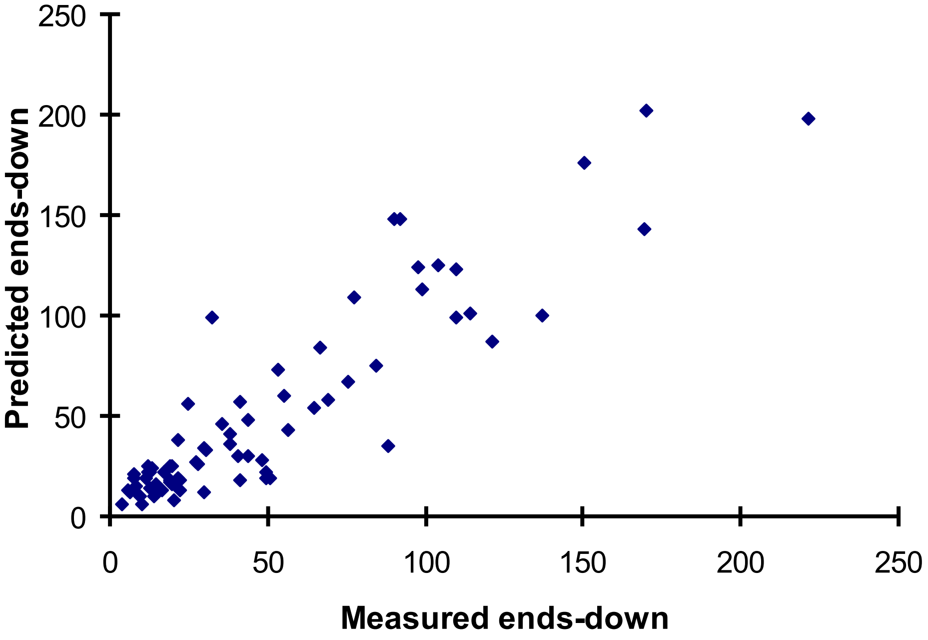

Figure 4: Predicted versus measured ends-down per thousand spindle hours.

Diameter μm	20	21	22	23	24
No. of fibres	46	42	38	35	32
CV% (evenness)	18.7	19.5	20.4	21.2	22.1
Ends-down/1000 sp. hrs.	15	26	49	98	215

(Using: Nm 50, 20 Tex, 636 tpm, CV_D=23%, H=70 mm, fibre tenacity = 11.12cN/tex, re-combed, spun at 9 000 rpm with #27 traveller on 55 mm rings.)

Table 1: Yarn evenness (CV%) and ends-down in spinning as a function of fibre diameter.

The spinning performance varies very rapidly with mean diameter. Forty to 50 ends-down per 1000 spindle hours is about what is just commercially acceptable in high labour cost countries such as the USA, Japan and Europe. So, for the middle wool with a mean fibre diameter of 22 μm, the effect of CV_D is shown in Table 2.

CV_D%	18	20.5	23	25.5	28
CV% (evenness)	19.5	19.9	20.4	20.9	21.5
Ends-down/1000 sp. hr.	26	35	49	72	112

Table 2: Effect of CV_D on yarn evenness (CV%) and ends-down in spinning.

The extremes, which are about the extremes observed in sale lots, show an effect of roughly that which would be achieved by a shift of 1 µm in mean diameter. However, a mill is unlikely to encounter values outside the range of 20.5 to 25.5% in a consignment of 22 µm wool, unless wools of grossly different diameter have been blended together.

The effect of Hauteur is illustrated in Table 3 for the yarn of Tables 1 and 2 with D=22 µm and CV_D=23%.

Hauteur mm	50	60	70	80	90
CV% (evenness)	21.1	20.7	20.4	20.0	19.7
Ends-down/1000 sp. hr.	228	92	49	29	19

Table 3: Effect of Hauteur on yarn evenness (CV%) and ends-down in spinning.

Longer fibres lead to slightly more even and significantly stronger yarns and so to substantially fewer ends-down in spinning.

For the wool and yarn of Tables 1, 2 and 3 with D=22 µm, CV_D=23% and H=70 mm, the effect on ends-down of 10% changes in bundle tenacity is shown in Table 4. The evenness is not shown because it is unaffected by bundle tenacity.

Bundle Tenacity cN/Tex	9	10	11.12	12.24
Ends-down/1000 sp. hr.	123	73	49	37

Table 4: Effect of bundle tenacity on ends-down in spinning.

Comparison with Tables 2 and 3 indicates that a 10% change in bundle tenacity (BT) has a similar effect to a 6 mm change in Hauteur or a change of 2.5 in CV_D% (other simulations give a trade-off of up to about 9 mm per 10% change in BT). The range of BT in commercial consignments has not been well studied but, for constant fibre diameter, we would not expect the range to normally exceed +/- 10%. However, it seems likely that BT of wool can be lower if sheep are stressed (disease, nutrition or environment) or if the fibres are damaged by a chemical treatment (including dyeing and shrink proofing). From the above considerations we rate the fibre properties in order of importance, in terms of their effect on spinning, as D, H, BT and CV_D.

It is important to realise that we are not, therefore, recommending to spinners that a specification for a 22.2 µm wool should have, for example, H > 95 mm, BT > 11.5 cN/Tex and CV_D < 18%. Such a specification would be absurd; although one such wool top has been produced (47). Instead, the improved knowledge of the relative importance of the various fibre properties should allow the topmaker and spinner to optimise the top purchase for the desired product and performance. To take an extreme example, the above top might be offered to a customer in place of a 19.5 µm, H=65 mm top with BT=10 cN/Tex and CV_D=23%, for use in a 17.9 Tex (Nm56) yarn to be two-folded and woven. Yarnspec would predict the singles yarn properties and spinning performance shown in Table 5.

Top	Diam. (µm)	CV-D (%)	Hauteur (mm)	Bundle tenacity (cN/Tex)	Yarn evenness (%)	Yarn tenacity (cN/Tex)	Elong. (%)	Ends-down per 1000 sp. hrs.
A	19.5	23	65	10.0	19.4	6.19	10.7	47
B	22.2	18	95	11.5	9.8	6.78	17.7	21

(Assuming: both tops are re-combed and spun at 673 tpm on 48 mm rings at 10 000 rpm using traveller #28.)

Table 5: Yarnspec predicted singles yarn properties and spinning performance.

The long Hauteur top could also be spun at a lower twist, which would give higher production in spinning and improved fabric handle that might go some way towards compensating for the softer handle of the finer wool.

Conclusion

Sirolan-Yarnspec is a quality control tool, which should enable the spinner to more reliably predict yarn properties and spinning performance. The predictions apply only to pure wool worsted yarns and now need extensive validation and ongoing refinement in the light of industrial trials. The predictions take yarn properties into account and provide a simple means of testing possible trade-offs between mean fibre diameter, diameter distribution, length and strength. This new tool should improve the communication between the top maker and spinner and allow the more careful tailoring of the top properties and price optimisation to best meet the spinner's needs.

References

1. D.E.A. Plate, 'What are the Wool Characteristics which are of Importance to Wool Processors and End Users?', CSIRO Division of Wool Technology, Geelong, 1990.
2. S.Yang, M. De Ravin, P.R. Lamb and N.G. Blenman, Proc. Top-Tech 96, CSIRO Division of Wool Technology, Geelong, 1996.
3. J.G. Martindale, J. Text. Inst., 1945, 36, T35.
4. D.M. Johnson, 'Investigations into the Making of Significantly More Even Wool Yarns', PhD thesis, University of New South Wales, 1994.
5. P.R. Lamb, J.Text.Inst., 1987, 78, 88.
6. P.R. Lamb, J.Text.Inst., 1987, 78, 101.
7. L. Hunter, Proc. 6th Int. Wool Text. Res. Conf., Pretoria, 1980, 1, 133.
8. J.L. Spencer-Smith and H.A.C. Todd, J. Roy. Stat. Soc., 1941, Supplement, 7, 131.
9. G. M. Bornet, Text. Res. J., 1964, 34, 381.
10. P.R. Lamb, Wool Tech. and Sheep Breed., 1992, XL(2), 65.
11. G. de Groot, Wool Tech. and Sheep Breed., 1992, XL(2), 60.
12. WIRA Textile Data Book, WIRA, Leeds, 1973, B83.

13. P.R. Lamb, G. de Groot and G.R.S. Naylor, Proc. Aachener Textil-Tagung, DWI Reports, Aachen, 1993, 599.

14. M. Bona, Industria Laniera tanda, 1994, 108(3), 188.

15. G.R.S. Naylor and D.G. Phillips, Proc. 9th Int. Wool Text. Res. Conf., Biella, 1995.

16. G.R.S. Naylor, IWTO Technical Committee, Report No. 8, Harrogate, 1995.

17. G.R.S. Naylor, D.G. Phillips and C.J. Veitch, Wool Tech. Sheep Breed., 1995, 43(1), 69.

18. P.R. Lamb, Proc. of Adv. Workshop on the Application of Mathematics and Physics in the Wool Industry, WRONZ, Canterbury, New Zealand, 1988, 161.

19. R.L. Bratt, J. Text. Inst., 1965, 56, T62.

20. M.G. Haigh and P.R. Lamb, Report GC143, CSIRO Division of Wool Technology, Geelong, 1994.

21. S. Yang,'The Effect of Fibre Length Distribution and its Shape on Yarn Evenness and Tensile Properties', Restricted Investigation Report, CSIRO Division of Wool Tech., Ryde, 1993.

22. L. Hunter and E. Gee, Proc. 6th Int. Wool Text. Res. Conf., Pretoria, 1980, III, 327.

23. J. L. Spencer-Smith, J. Text. Inst.,1947, 38, p. 257.

24. G. Mandl, Text. Inst. and Ind., 1981, 7, 212.

25. J.W.S. Hearle, 'Theory of Mechanics of Staple Fiber Yarns', in J.W.S. Hearle, P. Grosberg and S. Backer, *Structural Mechanics of Fibers, Yarns and Fabrics*, John Wiley and Sons, 1969.

26. S.Yang, 'Influence of Wool Fibre Characteristics on Worsted Yarn Strength and Extensibility', CSIRO Division of Wool Technology, Ryde, 1994.

27. D.E.A. Plate, G.A. Robinson and R.A. Rottenbury, J. Text. Inst., 1987, 76, 269.

28. D.W.F. Turpie and E. Gee, Proc. 6th Int. Wool Text. Res. Conf., Pretoria, 1980, III, 293.

29. A.D. Bastawisy, W.J. Onions and P.P. Townend, J. Text. Inst., 1961, 52, T1.

30. P.R. Lamb and S. Yang, CSIRO Division of Wool Technology, Report WT96-01, Geelong, 1996.

31. K. Tautenhahn, Int. Text. Bull., 1994, 1, 30.

32. D.W.F Turpie and L. Hunter, SAWTRI Tech. Rep. No.253, 1975.

33. G. Nitschke, Melliand Textilber., 1979, 60, 11.

34. E. Gee, Proc. 7th Int. Wool Text. Res. Conf., Tokyo, 1985, II, 85.

35. P.R. Lamb and S. Yang, CSIRO Division of Wool Technology, Report WT95-01, 1995.

36. K.A. Hansford, Wool Tech. and Sheep Breed., 1992, 40(1), 2.

37. P. Hynd, Proc. of Workshop on Future Trends in the Apparel Wool Industry, CRC for Premium Quality Wool, Western Australia, 1994, 128.

38. S. Yang and P.R. Lamb, "A Literature Survey on Wool Fibre Intrinsic Strength", CSIRO Division of Wool Tech., Sydney, 1995.

39. S. Yang, N.G. Blenman and P.R. Lamb, Proc. of Third Asian Textile Conference, Hong Kong, 1995.

40. L. Hunter and S. Smuts, SAWTRI Technical Report No. 409, 1978.

41. C.E. Gore, C.S.P. Lee and R.V. Rogers, Proc.8th Int. Wool Text. Res. Conf., Christchurch, 1990, III, 329.

42. S. de Jong and L.J. Smith, Proc. of Adv. Workshop on the Application of Mathematics and Physics in the Wool Industry, WRONZ, Canterbury, New Zealand, 1988, 546.

43. S. Yang, R.L. Thompson, M. De Ravin and N.G. Blenman, Proc. 9th Int. Wool Text. Res. Conf., Biella, 1995, IV, 107.

44. P.P. Townend, A.R. Matto and P.C. Clegg, Text. May, 1973, 44.

45. *WOOLSPEC 94*, Proc. of a Seminar on Specification of Australian Wool and its Implications for Marketing and Processing, Ed. R.A. Rottenbury, K.A. Hansford and J.P. Scanlan, CSIRO Division of Wool Tech., Sydney, 1994.

46. K.O.A. Kurdo, L.J. Smith and K.J. Whiteley, IWTO Tech. Cttee Meeting, Jan. 1986, Report No. 1.

47. P.R. Lamb, G.A. Robinson and T.J. Mahar, Proc. of Top-Tech ‘96, CSIRO Division of Wool Technology, Geelong, 1996.

48. D. Stevens and T.J. Mahar, Proc. 9th Int. Wool Text. Res. Conf., Biella, 1995, V, 134.

49. T. Madeley, T.J. Mahar, R. Postle, Proc. 9th Int. Wool Text. Res. Conf., Biella, 1995, II, 182.

Questions

1. What is the main determinant of the price of Australian wool?
   a. Fibre length
   b. Fibre strength
   c. Fibre diameter
   d. Curvature
2. What is Sirolan-Yarnspec?
3. For a yarn where the count and twist remain constant and all fibre properties except fibre diameter are kept constant, what is the effect on spinning performance of increasing fibre diameter?
4. From the work conducted in developing Sirolan-Yarnspec, in order of importance, what are the two most important fibre properties in spinning wool worsted yarns?