17. Future Developments in Wool Metrology

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Learning objectives

- By the end of this topic, you should have:
- an appreciation of the factors which drive developments in wool metrology; and
- a guide to possible future developments in wool metrology.

Key terms and concepts

Fleece testing, presale testing, top testing, testing for certification, spectroscopy.

Introduction to the topic

This topic briefly describes the framework in which future developments may occur in wool metrology and provides examples of possible developments.

17.1 Brief history

Two major developments in the middle of the twentieth century led to the development of wool metrology: the development of core sampling of wool bales by the US Department of Agriculture in the 1930's, and the development of Airflow testing of diameter in the 1940's and 1950's (Sommerville 2002). Core sampling provided a means of readily obtaining representative samples from greasy and clean wool bales, and the use of Airflow for the measurement of mean fibre diameter (MFD) enabled the development of a relatively cheap and simple alternative commercial test to microscopic examination of individual wool fibres.

These developments were followed in the 1960' and 1970's with commercial testing of regain, for both clean and greasy wool, and wool yield for greasy wool. The concept of presale testing of wool, rather than subjective appraisal gradually gained acceptance in Australia during this period. There was also a fundamental change from assessing capped bales of wool to assessing Display Samples consisting of a series of grab samples extracted from each bale in a lot, i.e. Sample by Sample. Testing of Staple Length and Staple Strength was introduced in the 1980's and was beginning to gain acceptance by the end of the decade. The next introduction of a major new measurement technology occurred in 2000 with the introduction of Laserscan, which provided measurement of the standard deviation (SD) and coefficient of variation of diameter (CVD), comfort factor (CF) and mean fibre curvature (MFC).

Each of these developments was implemented to aid in the specification of wool lots for trading purposes, and so Standard procedures were developed to ensure that measurements were repeatable, and accurate and precise within acknowledged boundaries. The most commonly employed Standards for wool testing in Australia are the International Wool Textile Organisation (IWTO) Standards (IWTO-19-03). Sampling regimes compatible with these Standards are set out in the IWTO Regulations. These Standards and Regulations developed in parallel with the development of the testing instruments. A full listing of current IWTO Standards concerned with raw wool testing is included in Table 17.1. IWTO Draft Standards are also available for many of the characteristics included in the full Standards, plus, for example, counting contaminant coloured fibres, mothproofing, wool fibre length, Chemical residues testing and the diameter of fibre ends.

Table 17.1 Listing of IWTO Test Methods concerned with Raw Wool Testing. Source: Mahar and Sommerville AWTA (2006).

Code Number	Full Title
IWTO-2-96	Method for the Determination of the pH Value of a Water Extract of Wool
IWTO-3-86(E)	Methos of Test for the Acid Content of Wool
IWTO-6-98	Method of Test for the Determination of the Mean Diameter of Wool Fibres in Combed Sliver using the Airflow Apparatus
IWTO-7-00	Sub-Sampling Staples from Grab Samples
IWTO-8-97	Method of Determining Fibre Diameter Distribution Parameters and Percentage Medullated Fibres in Wool and Other Animal Fibres by Projection Microscope
IWTO-10-03	Method of Determination of the Dichloromethane Soluble Matter in Combed Wool and Commercially Scoured Carbonised Wool
IWTO-12-00	Measurement of the Mean and Distribution of Fibre Diameter Using the Sirolan LASERSCAN Fibre Diameter Analyser
IWTO-17-03	Determination of Fibre Length Distribution Parameters by means of the Almeter
IWTO-19-98	Determination of Wool Base and Vegetable Matter Base of Core Samples of Raw Wool
IWTO-20-69(E)	Method for the Determination of the Felting Properties of Loose Wool and Top
IWTO-28-00	Determination by the Airflow Method of the Mean Fibre Diameter of Core Samples of Raw Wool
IWTO-30-98	Determination of Staple Length and Staple Strength
IWTO-31-02	Calculation of IWTO Combined Certificates for Deliveries of Raw Wool
IWTO-32-82	Determination of Bundle Strength of Wool Fibres
IWTO-33-98	Determination of Oven-Dry Mass and Calculated Invoice Mass of Scoured and Carbonised Wool
IWTO-34-85(E)	Determination of Oven-Dry Mass and Calculated Invoice Mass, and Calculated Merchantable Mass of Wool Tops
IWTO-35-03	Method for the Measurement for the Colour of Sliver
IWTO-38-91(E)	Method for Grab Sampling Greasy Wool from Bales
IWTO-41-92(E)	Determination of the Invoice Mass of Scoured or Carbonised Wool or Tops or Noils by Capacitance Method
IWTO-47-00	Measurement of the Mean and Distribution of Fibre Diameter of Wool using an Optical Fibre Diameter Analyser (OFDA)
IWTO-52-96	Conditioning Procedures for Testing Textiles
IWTO-55-99	Method of Automatic Counting and Classifying Cleanliness Faults in Tops using the Optalyser Instrument
IWTO-56-03	Method for the Measurement of Colour of Raw Wool
IWTO-57-98	Determination of Medullated Fibre Content of Wool and Mohair Samples by Opacity Measurements using OFDA
IWTO-58-00	Scanning Electron Microscopic Analysis of Specialty Fibres and Sheep's Wool and their Blends

17.2 Current situation

Available measurements

In 1982, CSIRO introduced a table of raw wool parameters which listed wool properties in order of importance to a wool buyer (Haly 1982) as shown in Table 17.2.

Table 17.2 Relative importance of Raw Wool properties. The greater the number of '#' symbols the more important is the wool property. Source: Haly (1982).

Wool Property	Relative Importance
Yield	# # # #
MFD	# # # #
Vegetable Matter Content	# # # #
Fibre Length	# # #
Strength and position of Weakness	# # #
Colour/coloured fibre	# # #
Fibre diameter variability	# #
Fibre length variability	# #
Degree of cottedness	# #
Crimp and resistance to compression	# #
Staple Tip	#
Age and breed	#
Style, character, handle	#

We are currently at the stage where all the 3 and 4 '#' parameters, and three of the four 2 '#' parameters have commercially available measurements (if we can assume that staple length is sufficiently well related to fibre length), though the test for contaminant dark fibre is only available in top form, or for contaminants introduced from contact with 'exotic' breeds of sheep in raw wool testing. The final 2 '#' parameter, degree of cottedness, has not been quantified, though 'cottedness' is only relevant to a very small proportion of the wool clip, and recent trials (Fish, Marler and Mahar 2004) have shown that some (significantly) cotted wool processes in a predictable manner based on the standard raw wool tests. The CSIRO Style machine has been able to quantify the shape of a staple tip, overall style and character of wool staples. The age and breed of sheep is readily specifiable. Prediction of wool handle based on other raw wool properties has also been demonstrated (Stevens, pers. comm. 1994).

As detailed throughout this series of topics, it appears that measurement technologies exist for all the wool properties nominated by CSIRO in Table 17.1. However, IWTO Standards exist for: yield, MFD, vegetable matter, staple length, strength and position of weakness, clean colour, fibre diameter and staple length variability. Further, test houses have emerged to meet the demand for high-volume presale core testing of sale lots of wool. These test houses have highly mechanised systems for wool testing which effectively mean they perform as wool testing factories, rather than as testing laboratories in the traditional sense. As with all of the test results, there is no compulsion to have wool tested. Wool testing is performed on a fully commercial basis, unlike testing for cotton and in the USA or wool in the UK, where marketing Boards require testing in order for producers to be eligible for market support payments.

There has also been recent growth in the testing of individual sheep, both on-farm and in test houses, and some interest in using on-farm testing to eliminate the need for certified testing in centralised test houses.

Areas of current usage

The are five different areas in which raw wool measurements are used, viz. trading, prediction of expected performance, performance monitoring (quality control/assurance), product and/or process development, and marketing.

Trading
Most trading in wool occurs when farm lots are sold to be accumulated into processing consignments. This trade relies on IWTO Standard measurements for yield (including vegetable matter base), MFD, staple length and strength measurements. Other measurements which are sometimes requested in this trade include: CVD, CV(SL), clean colour and MFC.

Measurements are also used to value individual animals, especially rams, in which case MFD, SD, CVD, comfort factor, MFC, yield, staple strength are often used.

Commercially scoured wool and wool top are traded based on regain and residual grease, MFD and, possibly, colour measurements based on IWTO Standards. Wool top is also measured for fibre length (hauteur) and variation in fibre length according to IWTO Standards.

Performance monitoring
Raw Wool measurements are used in performance monitoring (or Quality Control) during scouring (e.g. colour measurement) and combing (e.g., MFD, Hauteur, CV(Hauteur)).

Prediction
Raw Wool measurements are used to predict Top and Scoured Wool specifications, e.g. TEAM equations (TEAM-3 Steering Committee 2002), clean colour (Mahar, Osbourne and Burke 1996), Top and Noil Yields (IWTO Regulations), Length after Carding (Mahar, Osbourne and Burke 1996).

Product and process development
Examples of the use of Raw Wool measurement in Process and Product Development include, Glacial® wool from WRONZ (Ranford, Ellery and Wall 2002), fleece testing to improve clip preparation and sheep selection, process improvement in scouring, carding, combing, and spinning.

Marketing
Raw Wool measurements are used to provide market information about price trends and relationships between wool properties and price or wool supply. They can be used to discern niche markets for wool with particular properties (e.g. Elite type wool), as well as in supply chain partnerships in which wool producers, or groups of producers, link with an individual processor and spinner, fabric and/or garment manufacturer.

17.3 Future developments?

Relevant trends in wool production, trading and processing
There are several trends in the Wool Industry which may influence, or even guide, future developments in Wool Metrology. There is considerable interest in the use of on-farm testing as a means of improving clip preparation, sheep selection and, possibly, specification (certification) of sale lots (Baxter 2002).

There continues to be interest in establishing niche markets for specialised, or particular, 'types' wool based on geography, e.g. Tasmanian Merino, or sheep stud/line, e.g. Egelabra, wool properties, e.g. Elite wool, or growing conditions, e.g. 'organically grown' wool. These are examples of wool producers trying to establish closer links with potential clients further along the wool processing chain. Indeed, a major wool broking company, Elders, has purchased interests in a major early stage processing company, BWK, so that all processes from the farm gate to provision of wool top are under the control of one company.

The fantastic gains in computing and communications, e.g. through the internet, also offer potential to change aspects of wool trading. There are now technologies to accommodate the huge information load which metrology can generate to specify wool properties. Could we see trading in wool which is 100% specified, rather than being available for viewing and handling?

Predictions, like TEAM, appear to be improving as they are refined, offering a climate of greater certainty for production planning in early stage processing.
There is a trend towards greater use of raw wool measurement in breeding strategies and in ram judging.

And there has been a definite shift in early stage processing from Europe, Japan and Australia to China, and to a lessor extent India, over the last 5 years.

There is a trend for the introduction of new measurement technologies without the support of rigorous metrology previously provided through WIRA, ITF, CSIRO, WRONZ, and University of NSW. This lack of comprehensive metrology has hindered the uptake of new measurement technologies in recent years (e.g. fibre curvature).

A recent trend has seen the use of fibre diameter measurements of fabrics to verify the stated quality, e.g. '120's' or '140's' of worsted fabrics, especially high quality menswear. The IWTO has introduced its expected Mean Fibre Diameter values for nominated wool qualities, e.g. "Super 180's has a maximum fibre diameter of 14.75μm"[1]. There is need for further metrology to provide a reliable basis for verification. Metrology topics include:

- sampling from fabrics;
- dispersion of fibre snippets to ensure multiple snippets are not included as individual fibres in measurement, including from highly compacted or entangled fibres from crepe and flannel fabrics;
- the effect of dyestuff and finishes (shrinkproofing, handle modifying resins etc.) on diameter; and,
- the relationships between the MFDs of the top, yarn and fabric stages of fabrication.

One novel approach to verifying the wool quality in a finished fabric or garment has recently been introduced by Australian Wool Innovation (AWI). The Verification of Australian Merino (VAM) project seeks to verify the origin of wool in final products for marketing purposes. VAM checking is performed by AWTA Ltd based on tracing the original AWTA Ltd certificates for testing of the greasy wool sale lots. The increasing value to product marketing of the wool quality and origin of wool information has lead to these innovations, which have metrology implications. It will be interesting to see whether or not these approaches become commercially viable for the wool industry of the future.

New measurement technologies

Spectroscopic measurements

In recent years Near Infrared Reflectance (NIR) has been introduced to both performance monitoring (especially in scouring companies in New Zealand – Ranford, Ellery and Wall (2002) and certified Testing (IWTO-19). NIR is now used for moisture and residual grease content measurement, colour and even for approximate measurements of MFD by wool scours, and for residual grease and ash content of scoured core samples in presale certificate testing.

In principle NIR spectroscopy relies on calibration to existing measurement technologies and relates the quantity of a given non-wool contaminant (e.g. grease) to absorption patterns over a range of wavelengths. They offer a faster, simpler measurement than traditional method. It may be possible to extend this technology to on-farm yield testing (i.e., determining the proportion of wool in a sample of greasy wool) and so provide a means of specifying sale lots based on on-farm testing. X-ray scanning, as used in security checks at airports, has also shown potential in this regard.

[1] IWTO Blue Book, Arbitration Agreement and Other International Agreements, Version 08.2006, International Wool Textile Organisation, Appendix 2 Fabric Labelling Code of Practice, R05.

In short, the use of spectroscopy has provided a means of replacing traditional methods of measurement of residual grease and dirt in core scoured wool for certification. It is conceivable that spectroscopy in some form, e.g. NIR, X-ray, gamma radiation, or in combination, may provide a simple direct estimate of wool base and vegetable matter base, thus negating the need for much of the current testing regime for these two properties.

Image analysis

Comparatively little use is made of image analysis in wool metrology. Over the past 30 years major gains have been made in this technology, yet their application to wool metrology has been limited to diameter measurement for certified testing, and extended to curvature, and style characteristics for non-certified testing.

Future developments could see image analysis applied to the detection of dark and medullated fibre (DMF) and other contamination, including the identification of vegetable matter in core samples.

Electronic information

The use of radio frequency (RF) ear tags to identify individual sheep may be introduced in the foreseeable future in Australia. This has the potential to improve information flow and reduce costs in the testing of wool from individual sheep. Increased demand for such testing would drive improvements in fleece testing technologies.

There is also great potential to increase the use of modern information and communication technologies along the supply chain amongst producers, traders, early stage processors, spinners, weavers, knitters and garment manufacturers.

Refinement of existing measurements

Improvements are always being made to existing certifiable measurements in terms of their precision, accuracy, speed, simplicity and cost. Potential changes in current technologies could include:

- improvement of diameter calibration for measurement of ultrafine wool
- provision of the decrimped staple length in addition to the staple length of sale lots
- knowledge of the relationship between fibre diameter and fibre length in tops (using the OFDA4000)
- introduction of a calibration system for fibre curvature
- provision of an inexpensive measurement of staple crimp
- development of an estimate of the mean fibre length within a staple to improve processing prediction
- development of a simple fibre strength measurement
- a prediction of greasy wool softness based on current diameter and curvature technologies
- development of inexpensive measurements of fibre entanglement in a staple and the shape of staple tips
- derivation of a set of parameters from fibre diameter profiles (fdp's) to predict Staple Strength.

Other techniques which are unlikely to develop furthering the short term include: measurement of fibre ends, measurement of felting propensity of wool.

Individual fleece testing

The recent introduction of new technology, including OFDA2000 and Fleecescan, has initiated increased interest in on-farm testing. Further utilisation of these technologies awaits advances in metrology to aid in the interpretation of, for example, fdp's and fibre curvature values. Attempts are being made to develop robust predictions of staple strength and top hauteur based on fdp's.

The development of a simple spectroscopic-based measurement of wool base, and possibly vegetable matter base, will see, in theory, an improved capacity over current methods to specify producer sale lots of wool on-farm. Whether or not any new developments can meet the accuracy, precision and costs necessary to provide an alternative to current sale lot testing systems remains to be seen. The advances in fleece testing (both on-farm and in the test houses) have the capacity to provide quicker gains through genetic selection, and better utilisation of wool through improved selection of clip lines. The use of RF tagging and the ready availability of cheap computing and purpose-designed software provide the ideal means for producers to take advantage of these new technologies.

Presale testing

Foreshadowed developments in presale testing include:

- a decrimped staple length to supplement staple length measurement
- use of image analysis to detect dark and medullated fibre contamination
- a staple crimp measurement for sale lots, and
- a calibration procedure for fibre curvature measurement.

Other developments which may warrant research include the use of spectroscopy for the estimation of wool base, and image analysis for the quantification and identification of vegetable matter contamination.

Top testing

The OFDA4000 instrument (Brims and Baxter 2004) is currently available and undergoing comparison trials with Almeter and Laserscan instruments. The OFDA4000 provides estimates of length and length distribution parameters (including hauteur and barbe), estimates of diameter parameters including MFD, SD, CVD, CF, and the diameter of fibre ends, curvature parameters, and an estimate of the diameter profile of fibres in top. The instrument offers potential for measurements of fibre length and length/diameter relationships which have not previously been available. It is unclear how this new information will be applied in either the trading or product/process development areas. There is the potential that the additional information may improve processing prediction from greasy wool to top, and from top to yarn, and may even enable selection of fibres with particular fdp's in top to spin yarns with specialised characteristics, e.g. different combinations of surface softness and stiffness.

The detection and elimination of faults, e.g. neps, vegetable specks, dark and medullated fibres, in top is currently an expensive operation which is usually performed manually. There is currently a technical solution to this problem, the Optalyser, an image analysis instrument for fault detection, but it is prohibitively expensive and not widely used. With advances in image analysis, it seems likely that a cheaper system may be developed for fault detection in top.

Readings [3]

The following readings are available on web learning management systems

1. Australian Wool Testing Authority Ltd. (AWTA), 2002, Testing the Wool Clip, Glossary of Terms.
2. Baxter, P.B. 2002, 'Wool Metrology: Past and Current Trends and Future Developments,' Wool Industry, Science and Technology Conference – Innovation, Application and Opportunities, The State of Victoria, Department of Natural Resources and Environment.
3. Sommerville, P.J. 2002, 'Wool Metrology: Past and Current Trends and Future Developments,' Wool Industry, Science and Technology Conference – Innovation, Application and Opportunities, The State of Victoria, Department of Natural Resources and Environment.

Summary

Summary Slides are available on web learning management systems

Recent developments in wool testing instruments have been supported by limited metrology, e.g. fibre curvature and fibre diameter profile. The lack of in-depth supporting metrology may have contributed to the relatively slow uptake of these technologies. It is difficult to see this trend of slow uptake of new technology in wool testing unless major breakthroughs are achieved.

Aside from the incremental improvements noted in each category, fleece, presale and top, it is difficult to foresee a major development which would replace the current measurement systems in the short to medium term.

References

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Mahar, T.J., Osborne, L.J. and Burke, A.J. 1996, 'The use of Length After Carding for Australian carding wools,' *Proceedings. of IWTO,* Report No. 3, Nice.

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TEAM-3 Steering Committee, 2002, TEAM-3 Processing Trial – Final Report, *Proceedings. of IWTO,* Report No. RWG02, Evian, May, 2002.

Glossary of terms

Check Test	A Check Test is verification of documentation and calculations forming the basis of the Certificate on which a doubt has been raised and, if possible, a set of additional measurements made, in accordance with the same standard IWTO Test Method as was adopted for the original test, on that portion of the sample material remaining after that original test. Where no sample material remains, a Recore Check Test may be carried out as part of the check testing procedures. Check testing is restricted to tests carried out by the Test House, which conducted the original test
Recore Check Test	This is a set of measurements made, in accordance with the relevant IWTO Test Methods and Regulations, on a further sample of raw wool drawn from the delivery as part of the check testing procedures. A Recore check test may only be conducted where a Certificate has not been delivered in relation to a contract. Where staple measurements are involved this definition applies to a fresh grab sample taken from the lot rather than a core sample
Retest	This is a set of measurements made, in accordance with the relevant IWTO Test Methods, on a further sample of raw wool drawn from a delivery for which the original Certificate is in doubt. This differs from a Recore Check Test in that duplicate core (grab) samples are drawn for possible testing by two separate Test Houses to resolve a disputed result. Such sample material must be obtained by recoring (regrabbing) and reweighing all bales, in accordance with the current IWTO Core (Staple) Test Regulations
Testing Error	A Testing Error is deemed to have occurred if the Maximum Retest Range is exceeded
Maximum Retest Range	The Maximum Retest Range (i.e. the difference between the values of a retest and the original Test Certificate or an earlier retest) is a statistically (and scientifically) determined upper and lower limit which, provided the test procedure has been rigorously adhered to, will very rarely be exceeded purely by chance The Maximum Retest Range defines the maximum allowable difference between two test results

In addition to the above glossary, a comprehensive Glossary of Terms can be found as a reading for this topic (AWTA 2002.pdf).

Notes – Topic 17 – Future Developments in Wool Metrology