Raw-wool Metrology: Recent Developments and Future Directions

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Summary

This paper briefly reviews the history of commercial raw-wool metrology. Recent developments, particularly with respect to on-farm measurements, are discussed; and some current issues are highlighted. It is concluded that some of the more important challenges will be associated with the emerging on-farm technologies and their integration into, or interfacing with, quality assurance and descriptive metrology used by both traders and downstream processors. Much of the emphasis in the near future will be focused on improving sampling and testing accuracy and precision and on utilisation of the measurements both in farm management and in the prediction of processing performance of the product.

History

Much of the recent history of raw-wool metrology has been driven by the needs of international trading, primarily because the majority of commercial wool production has been in the southern hemisphere and the majority of the processing took place in the northern hemisphere. The International Wool Textile Organisation (IWTO) has been a primary focus for metrology development in this trading environment for more than 50 years, although a number of the early methods adopted by this organisation had their genesis within the American Society for Testing and Materials (ASTM) and, later, within Australasian Standards bodies. In general terms, new test methods intended for international use, other than those solely for research, are usually taken to IWTO for appraisal, subjected to peer review, and then qualified by means of international round trials before being accepted for publication as an IWTO test method. The standardisation process is often slow and expensive, especially more recently as procedural specifications for Standards development became tighter (Baxter 1996).

Core testing of raw wool was introduced as a concept in the 1930s in the USA, but it wasn't until 1954 that the Boston Wool Trade Association issued a circular whereby Bradford and American yields could be related for trading purposes. American yields were based on physical and chemical techniques, whereas Bradford yields used a purely mechanical method of analysis. In 1957, AWTA Ltd was established in Melbourne; in 1961, Wool Testing Services Ltd established a commercial core-testing laboratory in London; and in the same year, the British Wool Federation introduced regulations for core testing greasy wool for top and noil yield. The IWTO Core Test Technical Committee was formed in 1962, and the IWTO test method for yield (based on the American method) was finally adopted in 1968 (IWTO-19).

Projection microscopy started to become the most important method for determining the mean fibre diameter of wool from the early 1930s, but it wasn't until 1954 that IWTO finalised their test method (IWTO-8). Despite its impracticality for routine commercial work, it is the only primary reference method available and, as such, remains the reference method within IWTO. Airflow was first investigated as a diameter measurement method in the 1940s. It was adopted by IWTO for the measurement of tops in 1955 (IWTO-6); but it wasn't until 1975, however, that an airflow-based method was finally accepted for certifying raw wool (IWTO-28).

During the late 1950s and 1960s, IWTO focused on refining test methods for measuring those properties of wool directly relevant to processing and product performance, such as mean fibre diameter, fibre length distribution, residual fatty matter and cleanliness faults in tops, felting properties, bundle strength, and chemical properties. In Australia and elsewhere, investigations were also being carried out on the development of suitable large-scale mechanical sampling systems.

By the 1970s, developments in test methods for trading raw wool were starting to be driven from the southern hemisphere. "Sale by sample" was introduced in Australia in 1972/73. Factory-style test equipment was developed, and investigations were made of new technologies that could be put to use in raw-wool metrology. This decade saw the genesis of precursors to some current technology: the Fibre Diameter Analyser (FDA) (Lynch and Michie 1976), Vegemat (Winston *et al*. 1977), fibre diameter video analyser (FIDIVAN) (Edmunds *et al*. 1972), grab sampling (David and Andrews 1971), colour measurement (Hammersley and Thompson 1974), and near infra-red (NIR) spectroscopy (Higgerson *et al*. 1981). This period also saw some developments that came and went, including the Sonic Fineness Tester (David and Ward 1972), PiMc image analyser system (Pohle 1975), and the CSIRO Wool-base Analyser (Douglas 1971).

There was significant grower-funded research carried out in the 1980s into developing, commercialising, and validating staple-length and -strength sampling and testing methods. Commercial services were introduced in Australia in 1986, and IWTO-7 and IWTO-38 (sampling) and IWTO-30 (testing) were finalised in the early 1990s. During this period, development was also taking place on the FDA and its successor, the Sirolan Laserscan. The objective of these and other developments was to move to “sale by description” (Pattinson and Whiteley 1984); but over a decade later, this has not been achieved. Further development by CSIRO of systems for measuring “components of style” finally ceased in 2001, because the technology did not seem able to provide adequate reproducibility between instruments (AWTA Ltd *et al*. 2001). It was also considered that the technology would not deliver the measurements at a commercially acceptable price.

The Sirolan Laserscan and OFDA (now known as OFDA100) instruments became commercially available in the early 1990s and, after extensive technical debate, obtained full test methods (IWTO-12, IWTO-47, and for medullation by OFDA, IWTO-57), but concerns about small differences between these two technologies and airflow delayed full commercial implementation for raw-wool certification until the end of the decade. Draft test methods for colour measurement of raw wool and sliver were upgraded (IWTO-56 and 35), NIR spectroscopy became accepted as a submethod in the yield test (IWTO-19), scanning electron microscopy became accepted for analysing mixtures of wool and other animal fibres (IWTO-58), and chemical residue testing got as far as draft test method status (IWTO DTM 59). Along the way, comprehensive procedures were developed for assessing and progressing new test methods (IWTO-0).

So, where does that leave us? The answer depends very much on where you are in the chain.

The Standardisation Legacy

Almost all the developments I have quickly summarised have been aimed at assisting the trading of raw and semi-processed wool. However, these trading requirements have led to the development of a heavily prescribed sampling and testing system in the major wool-producing countries of the southern hemisphere, based on the measurement technologies and standard methods that have been developed.

IWTO Certificates are trading documents and can only be issued for test methods for which there are full sampling and retest regulations. These only currently exist for airflow on tops and raw wool; length distribution of sliver by Almeter; woolbase and vegetable matter base of raw wool; staple length and strength of raw wool; oven-dry mass of scoured, carbonised or tops consignments; mean and distribution of diameter by OFDA or Laserscan; and the colour of raw wool. Other test methods can only be used to issue test reports under IWTO rules, and these can only be binding between parties that have agreed to their use. Draft test methods (DTMs) also fall into this category. An important aspect of IWTO certification is that there are specified methods for dispute resolution, in that, associated with all methods for which IWTO certificates can be issued, there are regulations that cover retests and checktests.

IWTO requires laboratories issuing IWTO Certificates to be licensed. Licensed laboratories must be accredited to ISO 17025 by a qualified accreditation organisation, such as NATA in Australia; IANZ in New Zealand; SANAS in South Africa; or UKAS, COFRAC, or ENAC in Europe. This is an expensive process. This requirement was introduced in the 1990s long after very efficient laboratories had developed in the producer countries, each producing huge numbers of certificates qualifying the qualities and quantities of most traded lots and consignments of raw wool. In most cases, these laboratories had long since obtained accreditation.

Where raw wool gets turned into a first-stage product, however, we have a quite different story. The IWTO laboratory licensing system was originally intended to persuade mill laboratories to demonstrate that they complied with internationally accepted standards of quality control and that their certificates were within the accuracy and precision limits of the test methods. However, almost 5 years after the scheme was introduced, there are still only 12 IWTO-licensed laboratories in the world; and of these, 5 are the major commercial core test laboratories, only 3 are mill laboratories, and none of these are Australian mills. The fact is that most mill laboratories, where required by their customers, produce their own test documents instead of IWTO Certificates, while probably, in the main, following the IWTO test methods.

So why this dichotomy? Why is it that raw wool must be certified in a very regulated manner and yet, on the face of it, tops can be traded on the basis of a mill certificate? Traders tell us that tops must be produced to within

± 0.1 micron of the spinner's specification, and yet raw-wool contracts almost always specify a maximum value, which effectively implies no tolerance. Most raw-wool certification is carried out on farm lots, where, because the majority is still largely offered at auction, independent certification is considered vital. Raw-wool consignments can also be traded by relatively indirect routes. Downstream, however, a significant number of mills process direct to yarn or fabric and therefore have no need for independent trading certificates. Commission combers, because they are a relatively small group, tend to have established relationships with spinners, who check the consignments on receipt, so also have less incentive to require independent certification.

It's important to understand these issues, as they impinge on new developments. In essence, if measurements are used to describe wool that will be traded, especially if between parties with little in the way of trust, then third-party certification, and all the ancillary regulations that go with this, will be called for. When this happens, any new test method will have to go through all the processes that IWTO now requires. On the other hand, tests that are not used for trading certification purposes, i.e., effectively for some aspect of product management, quality control, or research and development, don't necessarily have to go through the same rigorous challenge. However, to become effective tools, they must still be adequately standardised; and their precision and accuracy must be sufficiently understood so that decisions based on their use are objective.

Test-method standardisation can be purely in-house for methods that are only used for quality control; but for wider acceptance and for comparing outcomes between different users, some form of nationally or internationally accepted process needs to be used. In some cases, user groups can develop methods and procedures; but if they need a wider acceptance, then standardisation at a national level, using organisations such as Standards Australia, will eventually be needed. A directly relevant example is AS/NZS 4492:2000, the joint Australian-New Zealand Standard for fleece testing. While very few fleece-testing laboratories are accredited against this standard, it does nevertheless provide the benchmark of good practice for fleece-testing laboratories and their clients to judge themselves against.

Current Technologies

The current accepted technologies for characterising semi-processed and raw wool are as follows.

Tops

Apart from commercial weight, regain and sliver linear density, the principal characteristics used to describe a consignment of tops against specification are shown in Table 1.

Table 1. Characteristics and technologies used to describe tops.

Fibre characteristic	Technology most commonly used
Mean diameter and diameter distribution	Airflow (IWTO-6), OFDA (IWTO-47) or Laserscan (IWTO-12)
Mean length and length distribution	Almeter (IWTO-17), WIRA Fibre Diagram (IWTO DTM 16), comb sorter (IWTO DTM 1)
Residual fatty matter	IWTO-10 or rapid grease test (in-house method)
Colour	Colorimeter or spectrophotometer (IWTO-35)
Dark fibre and cleanliness faults	Visual inspection (usually in-house method)

A significant number of mills still use airflow for diameter measurement, although most Western European mills are now using the newer technology. OFDA (Baxter *et al*. 1992) and Laserscan (Baird and Barry 1992) are developments of the 1980s, implemented commercially in the 1990s, using digital-image processing and a combination of laser photometry and imaging technology respectively. The Almeter (Monfort 1964) and WIRA fibre diagram (Anon 1948) can trace over 4 decades of history, and both use a capacitance sensing system for measuring prepared specimens. For the Almeter, the specimens are normally prepared using a complex mechanical device that is an integral part of the test: the Fibroliner. The basics of the rapid grease test are of some antiquity, using solvent to extract the grease, heating to evaporate the solvent, and then weighing of the residue. Some mills have more recently installed NIR instruments to measure both regain and residual grease, and possibly some of these instruments may measure colour as well by extending their spectral range into the visible. Wool colour has been measured using general-purpose colorimeters and spectrophotometers for several decades, but recent investigations suggest that results may only be reproducible between laboratories if they are using a limited range of instruments. Finally, visual inspection using balanced illumination is still relied on by most mills for quantifying cleanliness faults (IWTO DTM 13), although the Optalizer (IWTO-55), developed by

Centexbel, is now being installed in some larger mills that can justify the significant capital expenditure required.

Greasy Wool

The current principal descriptors of greasy and scoured or carbonised wool are shown in Table 2.

Table 2. Characteristics and technologies used to describe raw wool.

Fibre characteristic	Technology most commonly used
Woolbase	Scouring, drying and residuals measurement (IWTO-19)
Vegetable matter	Chemical methods (IWTO-19)
Mean diameter and diameter distribution	Laserscan (IWTO-12): combing wools (Aust, NZ, SA)
	OFDA (IWTO-47): combing wools (NZ)
	Airflow (IWTO-28): all other wools
Mean fibre curvature	Laserscan (combing wools only; not certifiable)
Mean length and length distribution	Staple length and strength (IWTO-30): combing wools
	Length after carding (NZS 8719): carding wools
Colour	Spectrophotometer (IWTO-56)
Residual grease (scoured/carbonised)	Soxhlet extraction (IWTO-10)

The determination of woolbase has remained a labour-intensive laboratory process, although the development of large laboratories has enabled utilisation of more efficient equipment and data-acquisition systems, thereby containing the cost by reducing the labour input. Otherwise, the only new measurement technology introduced to the method over the last few years has been the replacement of soxhlet extraction of residual alcohol-extractables by NIR instrumentation in the larger laboratories (Nissen-Wooller and Marler 1992; Baxter and Wear 1995). It is feasible that residual ash determination could similarly be replaced (Wear 2001). Vegetable matter determination also remains as a chemical method, although some degree of automation has been introduced in the major laboratories. The diameter and diameter distribution of the vast majority of combing wools are now measured by Laserscan, although some end users request OFDA measurements. In New Zealand, where crossbred wools predominate, the Airflow remains the method of choice.

Despite there being no recognised test method, mean fibre curvature is reported for Australian combing wools, based on Laserscan measurements (Lobb *et al*. 1998). The mean fibre length and other processing characteristics are routinely predicted from staple length and strength testing on combing wools, while for scoured crossbred wools, processing length can be predicted using the Length after Carding method (NZS 8719). The former relies on a generalised multiple regression equation (the TEAM formula) to which each mill must apply a mill adjustment factor, determined empirically after processing 10 to 20 consignments. The latter is based on a laboratory carding system that emulates a semi-worsted line. As with colour measurement on tops, the colour of laboratory-scoured or commercially-scoured wool is measured with colorimeters or conventional spectrophotometers, although the former will undoubtedly be phased out. Residual grease on scoured wools continues to be measured by the conventional soxhlet method, even though an NIR-based test method is available but currently lacks a sponsor to progress the method to full test method status (IWTO DTM 43).

Fleece Testing

Until very recently, fleece-testing services were provided by the raw-wool certification laboratories and other independent laboratories specialising in this business. The principal methods now used are washing yield (washing and drying of samples by a variety of methods) and mean and distribution of diameter, with curvature as required, by OFDA or Laserscan. A few laboratories still use the Airflow method. There is a reference standard available (AS 4492), but few laboratories follow it, most probably because, in contrast with the raw-wool certification system, there are no regulations arising from commercial pressures. In large part, these services are used for ranking animals; and unless used for clip preparation, it is difficult for the users to get any direct feedback about the quality of the service they have received; and hence, there has been little demand from the users for standardised testing services.

Over the last 2 years, many more independent operators have entered this arena, providing on-farm and in-store services. The two instruments being used are the OFDA2000, a portable version of the OFDA that measures the fibre diameter-length profile of greasy staples (Brims *et al*. 1999; Baxter 2001; Peterson and Gherardi 2001), and the Fleecescan, a combined fleece weighing, mini-coring/snippet cleaning system, and Laserscan (Hansford 1999; Humphries *et al*. 2001). Both instruments also provide mean curvature results. The advent of these two instruments has seen the size of the fleece-testing market triple in Australasia (Page 2001), although this still represents a small proportion of the total flock. Instruments of this category have recently also been introduced to South Africa, Argentina, Uruguay and the USA.

New Technologies

While one can't predict what new technologies may just be over the horizon, new technologies that have been announced can be briefly described.

Tops

For tops, there is now an IWTO draft test method for measuring the diameter characteristics of fibre ends (IWTO DTM 60). This parameter is of importance for next-to-skin wear (Naylor 2000). The test method was introduced by CSIRO in a contentious environment, with resistance being raised by topmakers fearful of yet another specification that they considered could potentially be used against them and for which they as yet had no method of prediction from raw-wool properties. The test makes use of the Fibroliner to align the ends of fibres, a special guillotine to cut snippets from the fibre ends, and an OFDA or Laserscan. One research team is looking at ways of predicting fibre ends using raw-wool characteristics and regression methods (Maher *et al*. 2002). Another is examining how data from the OFDA2000 fibre diameter-length profile on greasy staples can be used to predict this parameter (Peterson, pers. comm.).

A new instrument in the OFDA family, the OFDA4000, is at the stage of commercial testing (Brims 2002). This is designed to measure both fibre diameter and length distributions simultaneously on top samples and will also directly measure curvature and fibre-end characteristics. The manufacturer claims that the instrument could also be adapted to measure neps, dark fibres, vegetable matter, fibre strength, and possibly also medullation. Topmakers have shown strong interest in this instrument, and IWTO has now formed a working group to develop a test method for its use.

Raw Wool

At the raw-wool (certification) stage, there currently seem to be few new measurement technologies that have been announced other than the possibility of a dark-fibre detection test and an indication that research is under way to investigate the use of the Laserscan to measure medullation. Test houses continue, however, to improve the productivity of existing equipment and methods. Some new methods developed in the last decade have not been taken up by the market to the extent anticipated, in particular bulk (NZS 8716), resistance to compression (AS 3535) and medullation by OFDA (IWTO-57), although the commercial test houses do issue a limited number of test reports for these properties.

There has been a proposal to extend NIR measurements to include residual ash in the yield test (Wear 2002); and as indicated earlier, the same technology needs a sponsor to upgrade a draft test method for residual grease on scoured wool (IWTO DTM 43). Research work has been carried out in several laboratories on using NIR for predicting woolbase, fibre diameter, medullation, vegetable matter, colour and chemical residuals, but none of this has made its way further than implementation for quality-control purposes in a small number of commercial scours (Ellery *et al*. 2000).

Gamma- and x-ray techniques have also been explored for measuring woolbase and residual contaminants, but these are understood to be still at the development stage (Bartle 2001). Video imaging has been investigated for estimating the VM components in the yield test. A non-prescriptive draft test method has been developed for chemical residue analyses (IWTO DTM 59); and in New Zealand, a sophisticated enzyme-analysis technique is being used for lice-infestation quantification (MacLean 2002).

Fleece Testing

Developments in fleece testing have been rapid in recent years, probably in part due to the unregulated nature of this market. A number of laboratories have reduced costs by streamlining their preparation systems, and there are almost as many preparation systems in use as there are major fleece laboratories. However, there is also no information available, or systems to provide any information, that would indicate to users whether or not these innovations have had any impact on the quality of the services offered. This is one of the disadvantages of an unregulated and unquestioning market.

The implementation of on-farm and in-store systems using the Fleecescan and OFDA2000 have significantly changed the testing scenario in this area, and the promise of a relatively cheap hand-held device being promoted by Australian Wool Innovation will undoubtedly also have significant impact if it comes to fruition. It is feasible that there are other developments going on behind closed doors. Most of the focus has to date been on fibre diameter, but experiments with ionising radiation and NIR systems for yield and other contaminants have also been mentioned.

The availability of diameter-length profiles has stimulated the development of both on-farm feed-management procedures (Oldham *et al*. 2000) and processed-fibre length-prediction algorithms (Peterson 2000), and we can expect these to be made more widely available to growers in the 2002/03 season. It is also understood that AWTA Ltd are developing an alternative length-diameter profile measurement system based on normal staple measurement technology (Sommerville, pers. comm.), which will probably also stimulate demand for this data. While not strictly a metrology issue, we have also seen the emergence of on-farm decision-assistance software packages, designed to help a grower through the complex management issues that all help determine profitability from the sheep enterprise (Vizard 2001). It is to be expected that these will become more sophisticated in the near future, with options to calculate maximised returns per hectare and per enterprise, and for these to become better integrated with on-farm measurement systems. Certainly, there is a serious need for a more holistic approach to utilisation of on-farm measurements.

Current Issues

Fibre Curvature

In my view, the situation with fibre curvature is becoming increasingly untenable. The results of measurement are reported for combing wools in Australia, and yet there is no Standard available. A working group draft method put to IWTO has languished for some time (Ranford 2000). A number of investigations connected with fibre-curvature metrology have been reported, but these have mainly served to emphasise how difficult it is to obtain consistent results, particularly on raw wool (Fish *et al*. 2000). It has been found that virtually all aspects of sample preparation may have some systematic effect on the result. To date, there has also been no progress reported on finding a suitable universal calibration method. Unfortunately, the two instruments commonly used, OFDA and Laserscan, while both based on snippet measurements, vary both in their detailed sample preparation and in their method of determining, calculating, and data storage. There has been some progress on the use of graticules for confirming the calibration of OFDA instruments, but it would appear that this class of instrument is inherently relatively accurate anyway, and instrument calibration would therefore appear to be the least of the issues (Baxter 2002). This data does, however, suggest that curvature measurements on tops may be sufficiently reproducible to open the door towards a calibration mechanism. There has been little published to date on the accuracy or precision of curvature when measured on the Laserscan instrument. Finally, there is still considerable debate on the commercial value of the measurement, as was witnessed at the Commercial Technology Seminar on this subject, held at IWTO in Barcelona in May 2002. The work being carried out by AWTA Ltd on the TEAM-3 processing prediction project may help to highlight the value of the measurement.

Dark Fibre and Contamination Identification

In-bale contamination has been a major issue with processors for many years (Burbidge *et al*. 1993). The move to nylon packs was to have provided some relief on this issue (Blanchonette and Abbott 1997), although there has as yet been little formal confirmation that this has been effective. Indeed, there has been evidence that, in some cases, nylon-fibre contamination has caused problems. Nevertheless, the problems caused by foreign fibrous material included in bales still continue. Until recently, problems caused by black and pigmented wool fibres in bales were thought best controlled by risk analysis (Burbidge *et al*. 1991). However, the incidence of this fault is said to have risen seriously in recent seasons but not primarily through faulty breeding policies, *per se*, but by cross-contamination from introduced meat breeds and by the use of meat terminal sires. This has prompted a reassessment of the issues, and an urgent search for a method of detecting dark fibres in the core-test laboratory. At least two organisations are known to be working on this issue. Whether the outcome will be an instrument that will measure both dark fibres and other forms of in-bale contamination remains to be seen.

Tailoring Fibre for Specific Markets

There has been much talk recently of the desire to produce wool lots to fit specific market requirements – whether these are simply based on diameter or, more likely, incorporate additional parameters, such as diameter variability, curvature, processed length or style. Research is even being conducted on selecting sheep for shrink-resistant wool (Greeff and Schlink 2001), although it is likely to be some time before we see that translated into simple on-farm measurements, unless using predictive parameters. While instruments such as the OFDA2000 now include software to allow fleeces to be classified for multiple characteristics, there is some way to go before it becomes a straightforward issue for the grower to optimise his clip in such a complex manner.

While not primarily a metrology issue, feed management for improving wool characteristics is a relatively new idea that depends on recent advances in fibre metrology. There have been attempts to try to control staple strength using fibre-profile management (Peterson *et al*. 2000), but this goal has proven more difficult to implement than initially thought. One alternative now being trialed is to use periodic close-to-skin fibre-diameter measurements to monitor fibre growth and to use this data to then restrict feed intake during times of good pasture growth so as to even out the fibre length-diameter profile (Oldham *et al.* 2002). It is probable that an algorithm will be incorporated into the OFDA2000 during the 2002/03 season that will use the length-diameter profile to allow growers to estimate and manage the processing length of farm lots.

The concept of tailoring clips to suit specific or specialised markets does, however, depend on appropriate measurement accuracy and precision (see below).

On-farm Measurements and Quality Assurance

At the time of writing this paper, the issue of accuracy and precision of on-farm measurement was both a topical and controversial topic. The principal focus has been, of course, on mean fibre diameter measurement, but if this type of technology is to be used to select fleeces for other characteristics, then each parameter needs to be looked at in detail. Not only is the level of precision of measurement of each parameter important for maximising selection potential, but accuracy is vital if fleeces are to be selected to fit contract specifications. Currently, based on relatively limited comparative field trials, there are apparent differences in precision provided by the available technologies, although the magnitude and significance of these differences is a matter for debate and still subject to confirmation in replicated trials (Peterson 2001; Marler *et al*. 2002). It would appear that the technologies also have problems to be resolved in terms of providing adequate accuracy for a grower to meet a contract (Hansford *et al*. 2002). Once parameters other than diameter are introduced into the specification, the scale of the problem multiplies; and there is an urgent need for independent guidelines for growers who might decide to embark on this potentially risky path.

The quality assurance of commercial core-test laboratory results is audited by the appropriate accreditation authorities against ISO 17025 and is one of the core elements of IWTO Licensing. Another element is the requirement for these laboratories to participate in regular inter-laboratory trials to demonstrate their performance. Neither of these elements is either mandatory or even currently available on an industry-wide basis for fleece-testing laboratories and on-farm testing suppliers. While there was for many years a six-monthly fleece-testing proficiency trial available for participants in the Woolplan scheme and, subsequently, the Rampower project, this was discontinued recently. Each of the competing on-farm technologies claims to fully train the operators of the instruments; but at the date of drafting this paper, the only wide-scale proficiency trials being undertaken were the Interactive Wool Group (IWG) trials for OFDA2000 operators (IWG 2002). However, a vital aspect for users is that operators must routinely adhere to quality-control procedures, which are necessarily different for the two technologies. Clearly, for growers making significant management decisions based on fleece testing, this is not a satisfactory situation. Australian Wool Innovation is understood to be looking at ways of addressing this deficiency.

On-farm Fibre Certification

The idea of on-farm certification of lots has been promoted on a number of occasions. This goal is far from straightforward, however, even given all the necessary technology to provide the required measurements. One glaring deficiency in the latter respect is the need to measure yield and vegetable matter; and to date, this has not come anywhere near fruition, even though a number of organisations have looked at the problem. The other primary issue that needs addressing is on-farm sampling and weighing, because certification depends entirely on representative sampling and accurate weights. Portable mechanical coring equipment and grab sampling gear has been developed in Australia, and some performance data has been published (Sommerville 1997,8).

It is difficult to understand the real benefits that might accrue from on-farm certification. Admittedly, it may seem to give growers some options in terms of how they could sell their wool; but against that there are additional responsibilities, such as financially guaranteeing the quality of the wool and delivering it on time.

In New Zealand, under specific circumstances, lots can be certified from on-farm sampling and laboratory core testing; but the uptake of the service has not been widespread. In addition to the issues of maintaining bale security, there are additional costs associated with the weighing and sampling. While some private buyers will accept such lots, most major exporters are not prepared to buy lots offered in this way. Partly, of course, this is because of mistrust of unknown sellers; but also it is because of the inconvenience of their having to scrutinise an electronic sale board on a frequent basis (as opposed to dealing with well-organised scheduled auctions). Buyers also dislike having to deal with many small sellers and prefer to avoid the inconvenience of having to organise or ensure correct and timely delivery of the lots to the required destination. Given the limited geographic size of New Zealand, it is difficult to see how these difficulties could be easily overcome in a country the size of Australia.

Commercial Issues

There has been and will continue to be a challenge to meet commercial expectations with practical and cost-effective test methods and sampling regimes. As just one example, the precision of most diameter certification methods on individual sale lots is approximately ± 0.4µm at a mean fibre diameter of 20µm. The trade, however, works to specification limits quoted to 0.1µm and normally with no tolerance, although this applies to consignments, not individual sale lots. At 20µm, the precision of a combined certificate on an average 100-bale consignment is approximately ± 0.1µm; and this therefore gives no leeway for any short-term small systematic biases such as might arise from calibration (Baxter 1999) or laboratory processing changes. Similar problems exist for vegetable matter specifications and, on crossbred wools, with colour measurement and Length After Carding. It is therefore a continual challenge for test houses to improve the stability and precision of certification methods, especially when sampling remains the source of much of the natural variation; and improvements in this area cannot be made without significant increases in cost. This challenge is not new, but it is unlikely to diminish (Ward 1994). We are now also seeing the beginnings of the same sorts of constraints being applied to on-farm measurement systems, with grower expectations often far exceeding the current capabilities of the available sampling and testing methods.

Conclusions

This paper has reviewed some aspects of wool metrology as at 2002. It is not a static situation. Even so-called mature testing technologies continue to present challenges in terms of improving accuracy and precision and, in the commercial environment, reducing costs and turn-around times. Some of the greatest challenges, however, will be associated with the emerging on-farm technologies, and their integration into, or interfacing with, quality assurance and descriptive metrology used by both traders and downstream processors. Much of the emphasis will be focused on improving the sampling and testing accuracy and precision of these methods and on utilisation of the measurements both in farm management and in the prediction of processing performance of the products. It is to be expected that, within the next 5 years, we will see a wider range of measurements being offered on-farm and, in the longer term, more rapid measurement technologies being applied at all stages of the processing pipeline.

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