# Fibre Metrology of Wool and its Applicability to Alpaca

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### Summary

The measurements made on wool and the reasons for those measurements are examined. It is suggested that, if the alpaca fibre-processing industry is to move beyond being a cottage industry, it will have to adopt modern total quality management. It will also have to respond to customer demands for end-products at competitive prices and processor demands for repeatable quality. This will mean price will be determined by measured fibre properties and the key properties will almost certainly be diameter and whiteness (freedom from coloured fibre).

#### Introduction

Measurement is essential because subjective assessments of quality are inaccurate and not easily quantified. How would you feel if you were sold a "bullet-proof" jacket on the basis that someone could not poke their finger through it and it looked OK! The aim is to reduce risk which saves money because failures can have severe consequences. If the wool does not have the visually assessed diameter or is tender then it may not be possible to spin it into the intended yarn. Moreover, the more accurately you can predict performance the closer you can go to the allowed limits. An accurate prediction of yield means just the needed quantity of greasy wool can be bought. Predictability saves money.

For wool's competitors, both cotton and synthetics, it is possible to order by telephone from a range of suppliers a standard product that will be accurately the same each time in almost any quantity desired at a fairly stable and known price and with a short delivery time.

#### **Wool Measurements**

Every sale lot of greasy wool going through the auction system is core sampled and measured for yield and vegetable matter (VM), and mean fibre diameter. Currently, the diameter measurement is by air-flow, in which the flow of air for a constant pressure drop through a known mass of washed and opened wool is measured. This method is likely to be supplanted shortly by Sirolan Laserscan (1), a laser-based instrument which measures how much light is occluded by 2 mm long fibre snippets as they flow past in an isopropanol/water mixture designed to condition the wool to a known regain. The measurement also gives the range or distribution of fibre diameters present. This measurement is available (at additional cost) and if it has been made then this is noted in the sale catalogue.

About 70% of sale lots are measured for staple length and staple strength. The method involves taking a grab sample from a wool bale, randomly selecting tufts and then manually selecting staples and placing them in trays for automated measurement by the Atlas instrument (2). The length of each staple is optically assessed then the staple is gripped at both ends and the peak force required to break the staple is measured. The two broken parts are then weighed. The average staple length, variation in staple length, staple strength (normalised to the weight of the staple), variation in staple strength and the percentage of breaks in top/middle/butt of the staple are calculated. The position of break is determined from the relative weights of the two broken parts.

The advantage of measuring length and strength is in the ability it gives for predicting mean fibre length in the top (Hauteur) and the percentage loss in combing (romaine). This can be seen in the TEAM 2 formulae (3):

Hauteur = 0.52 SL + 0.47 SS + 0.95 D - 0.19 M\* - 0.45 VM - 3.5 Romaine = - 0.11SL - 0.14SS - 0.35D + 0.94VM + 27.7

where SL is staple length, SS is staple strength, D is fibre diameter, M\* is adjusted % middle breaks, VM is vegetable matter base.

A marked seasonal reduction in along-fibre diameter is particularly detrimental to achievable top length. The change in diameter is the main cause of reduced staple strength and both low staple strength and a high percentage of mid-breaks leads to reduced top length. Improving staple strength through management strategies, for example by additional nutrition, or changing the time of shearing so that the position of break is moved away from the centre of the staple, can lead to substantially higher prices depending on any penalty from increased VM contamination.

The TEAM (Trials Evaluating Additional Measurement) formulae are simple linear regression fits to data obtained from a large number of commercial mills. They have some limitations such as the inherent assumption that staple length is a good measure of average fibre length within the staple, and the lack of good information on along-fibre strength variation. It is expected than similar formulae will hold for alpaca fibre but this needs to be confirmed and is the subject of a current research proposal.

Wool fibres have a wide spread in diameter within sheep. For a sound wool most of the variation in a flock can be found between the fibres of any one staple of any one sheep. There is a small component of variation around the sheep and a degree of variation between sheep. The spread of diameters is given in terms of the standard deviation (SD) or the percentage co-efficient of variation ( $CV_D\% = 100 * SD / D$ ). Additionally, it is quite common to give the percentages of fibres coarser than 30  $\mu$ m.

It has been observed (4), for sale lots of Australian wool and tops, that the average  $CV_D\% = 10.5 + D/2$ , so that  $CV_D\% = 21$  for  $D = 21 \ \mu m$  and  $CV_D\% = 25$  for  $D = 29 \ \mu m$  etc. Recent measurements of mid-side samples (5) on alpacas in Australia appear broadly consistent with these average values, although the  $CV_D$  values of mid-side samples for sheep should be slightly lower than the values for sale lots. Stapleton and Holt (6) examined fleece characteristics on twenty alpacas from one property. Their results showed that the apron fleece averaged about 10  $\mu m$  coarser than the rest of the fleece and the britch area was slightly broader. At first sight this study seems to be contradicted by another study on 35 animals (7) but in the latter study the apron and britch areas were not examined. A spread of greater than ±3  $\mu m$  starts to have a significant effect on the  $CV_D$  values of whole fleeces. However, the apron area should be separated from the rest of the fleece based on its effect on the mean diameter alone.

The effect of a spread in fibre diameters is to make a collection of fibres behave as though they are a bit coarser than their average diameter. Thus a narrow distribution of diameters is preferable but a change in properties can usually be achieved more easily by breeding for reduced diameter than by breeding for reduced spread in diameter, although it appears possible in sheep to simultaneously select on both parameters.

The Laserscan and its rival the OFDA (Optical Fibre Diameter Analyser) measure the diameter distribution at the same time as the mean diameter. They also measure

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the curvature of snippets, that is the rate at which the direction of a fibre changes. The measurements of curvature of the two instruments are in good agreement and it is currently proposed that this measurement will be covered by a single new standard. Curvature is of interest because it is closely correlated with the measured crimp frequency of wool and some buyers pay more for highly crimped wools. Recent research results suggest that high levels of crimp (curvature) are slightly detrimental in processing and lead to tops and fabrics that are rated less soft (8). Crimp recovery when knitted fabrics are relaxed is larger for wools of higher crimp frequency and leads to a more bulky fabric with lower air permeability but there may be other ways to achieve similar bulk.

Historically, high crimp frequency was used to select for finer wool and, across the full spectrum of Merinos, diameter is still negatively correlated with crimp frequency. However, the correlation has been observed to be weak and even reversed in some superfine flocks (9). Ferguson (5) has observed that fibre curvature values are low in Huacaya and very low in Suri alpacas when compared with Merinos. In the case of the Huacaya there was a marked negative correlation between mean curvature and mean fibre diameter while for Suri it was weak.

For sheep the whiteness of greasy wool is not a useful indicator of the whiteness of the clean wool. However, a standard spectrophotometric measurement of colour after the greasy sample has been washed and the web randomised is now available (10). The same method should be applicable to coloured alpaca fibre.

An instrument, Sirolan Staplescan (11), has been developed for use in conjunction with the Atlas instrument. It has sophisticated video analysis capabilities that enable it to measure crimp frequency, crimp definition, amount and penetration of dust, tippiness, etc. The aim of this instrument is to quantify the so-called "style" properties that are currently visually assessed. If the need for visual assessment could be eliminated then sale solely by measurement would be possible.

The limitations of the current measurements in achieving very accurate prediction of mean fibre length in top and of romaine point to the need for additional measurements such as along-fibre diameter variation or fibre-to-staple length ratio. It has been suggested that "handle" is also a needed property. However, experiments have shown a good relationship between the product of crimp and diameter and handle (and resistance-to-compression) (12). It would be interesting to know how much the lower crimp of alpaca contributes to the perceived better handle.

A percentage of fibres in coarser wools are medullated which means they have hollow or part hollow cores. Medullation is almost non-existent in fine Merinos but is significant in alpacas. The OFDA is able to provide an estimate of percentage medullation of non-coloured fibre. As with sheep the percentage medullation has been observed to decrease with decreasing fibre diameter (5,6). A small hollow core will not significantly affect fibre properties such as bending stiffness or thermal conductivity. The serious disadvantage of medullation is the different dyeing behaviour of these fibres which can lead to skittery dyeing.

The above discussion of measurement has been in the context of the use of measurements for accurately pricing sale lots of wool and for predicting their processing performance. These measurements are normally made by a central test house such as AWTA Ltd on samples taken in the warehouse of a wool handler and following strict IWTO (International Wool Textile Organisation) standards. Currently, there are moves towards in-shed (i.e. on-farm) sampling. It is also quite common to make measurements on fleece samples for breeding purposes or valuation of animals. Recently, a set-up using a Laserscan together with snippet sampling and solvent washing equipment and fleece weighing has been trialled in

shearing sheds (13). The equipment takes a representative sample of each fleece and appears capable of keeping pace with a shearing rate of about 1000 sheep/day. When coupled with sheep tagging this enables both the accurate classing of fleeces according to measured properties and the measured assessment of each animal for breeding purposes.

Wool top is sold around the world based on its measured values. The key fibre properties are diameter and length (14). The latter measurement is primarily made with an instrument called an Almeter. Most mills will also put limits on neps (fibre entanglements), VM (particularly that longer than 10 mm) and, according to enduse, dark fibre content. The typical limit is no more than 10 dark fibres per 100g of wool. Most mills also put limits on the length distribution (CV<sub>H</sub>) or the short-fibre content, although the importance of these appears to be over-rated (15). A new method, Sirolan Tensor (16), for the measurement of average fibre strength in top has recently been applied to alpaca (5). The bundle tenacity of alpaca was observed to be slightly higher than that for wool of a finer diameter, however, the results were generally consistent with the values that would be expected for a wool of similar diameter (17). In the past there have been claims that alpaca fibre is stronger as evidenced by a higher staple strength (6), but it needs to be appreciated that staple strength is predominantly a measure of the change in cross-sectional area of the fibre which is mostly due to changes in nutrition. In one study (18), the changes in alongfibre diameter and the staple strengths of alpacas and sheep grazed together were very similar.

What measurement might be needed for alpacas that is not routinely used for wool? It seems that alpaca may be more severely affected by UV damage than wool. This may relate to the lower grease content, the animal's dust-rolling or the more open structure of some alpaca fleeces. Severe UV damage can reduce top length but the bigger concern is probably the effect on dye uptake. There are chemical staining tests to detect UV damage which have already been used to study the nature and severity of the problem in alpacas (6). It was found that the mid-back site is severely weather-damaged compared with the rest of the fleece. For sheep, a simple UV blocker applied after shearing can be 70% as effective as rugging (19).

#### **Customer Needs**

IWS (now The Woolmark Company) consumer surveys have shown that in garments of the same fabric construction, style and colour, softness to touch, next-to-skin comfort, lightness, and easy care dominate consumer preference (Figure 1) (20). The first three characteristics are determined largely by fibre diameter. Easy care basically means machine washability and minimum labour to keep the garment looking good. It implies chemical treatments such as shrinkproofing and is little influenced by fibre properties.



Figure 1. Preference Share Amongst Fabric Features, US Consumers

As pointed out by Plate (21) eight years ago there has been a continuing trend towards lighter-weight fabrics. In fact, it had even been suggested that if the trend continued for another twenty years we would all be wearing multiple layers of zero weight fabric! This trend, which saw average suiting weights drop from 350 g/m<sup>2</sup> to around 230 g/m<sup>2</sup> over 30 years, with light-weight suits down to 160 g/m<sup>2</sup>, has probably levelled out. The problem is that the really light fabrics do not hang well and are difficult to tailor.

Light-weight fabrics require light-weight yarns and the weight of a yarn is the product of the average number of fibres and the mass, per unit length, of the component fibres. Alpaca fibres are coarser than the bulk of the Australian wool clip and so cannot be spun into as fine yarns as wool. Finer fibres also give rise to stronger and more even yarns. The longer length of alpaca fibre helps but only marginally.

For wool garments which are to be worn next-to-skin the sensation of prickle is very important. It has been clearly established that prickle is caused by the coarse fibres in the fibre diameter distribution (22). A fibre that does not bend readily may be able to provide sufficient distortion of the skin to excite some pain receptors. Prickle is not an allergic reaction. It is very unusual to be allergic to wool, as its composition is very similar to human hair or fingernails. The number of fibres that can cause a prickle sensation varies with the fabric construction and sensitivity to, or perception of, prickle which varies from person to person, with age, with temperature and humidity (for example, from exercise). Thus, it is not possible to specify exactly the "prickle factor" although the percentage of fibres coarser than 30  $\mu$ m is often used as a rough guide, and about half the population will feel prickle if there is 5% of such fibres. A finer wool with a lower than average fibre diameter but a higher than average percentage of coarse fibres could provide a greater sensation of prickle than a broader wool with a narrow fibre diameter distribution. However, narrower distributions are not nearly as effective as finer diameters at reducing the coarse component and, for wool to be used in next-to-the-skin garments e.g. under-wear, it is wise to use wool finer than 20  $\mu$ m and preferably finer than 19  $\mu$ m. Indeed, it is in the long-term interest of wool apparel that only such wool be used next-to-the-skin. The use of relatively coarse wool (mostly of U.S.A. origin) has led to the widely held perception in the U.S.A. that consumers cannot wear wool against their skin.

I know of no published data on the next-to-skin comfort of alpaca fabrics compared to similar wool fabrics. However, given the similarity of the fibre to wool they could be expected to have similar "prickle" if the wool is of similar fibre diameter and the fabric of similar construction. The greater slipperiness of alpaca may mean that the fibres are less stiffly held in the fabric and slip more easily on the skin surface but experimental comparisons are needed.

# The Relative Importance of Fibre Properties for Spinning

The theoretical understanding of the expected effect of fibre properties on yarn characteristics together with results of CSIRO trials have led to a series of prediction algorithms within a user-friendly computer program (Sirolan-Yarnspec) (23). The algorithms are still being refined but have now had extensive industrial validation. The relative importance of fibre properties, which is encapsulated in these algorithms, can be summarised in a few simple statements:

- a) mean diameter is overwhelmingly the most important top fibre property.
- b) mean fibre length is the next most important and 10 mm of Hauteur can be traded-off against 1  $\mu$ m in mean diameter in terms of its effect on yarn tenacity and ends-down in spinning. For evenness, about 25 mm trades off against 1  $\mu$ m. Neither trade-off applies to fabric handle because it is fibre diameter that affects stiffness and softness.
- c) fibre length distribution has little effect on yarn properties and spinning performance.
- d) the importance of diameter distribution  $CV_D$  is as expected, with approx. 5% in  $CV_D$  trading-off against 1  $\mu$ m, for yarn and fabric properties and spinning performance.

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. The relative importances are also mostly reflected in the auction price of wool where about 70% of the price is determined by mean diameter and the next most important parameter is staple strength because of its effect on top length and losses (noil).

The production of superfine wool is increasing. AWTA Ltd has recently reported that superfine wool made up 15.4% of all wool tested compared with 8.8% only three years ago. However, it is believed that some of this apparent increase came from on-farm stocks. The demand for superfine wool is also increasing. It has been reported that China's purchase of superfine wool has risen by a factor of four and purchases by Indian mills are also showing big increases. These are both reflections of the move by these countries into the higher quality end of the market. The stockpile contains very little super-fine wool and averages more than 1 µm coarser than the clip average. This is a very clear demand signal.

The demand for wool will continue to fluctuate as it is partly driven by fashion. Currently, it is lightness and softness that are demanded and warmth-without-weight that is desired. Coarse wool will increasingly be seen as a lower grade product that will not be able to command a premium of a factor of three to four over its synthetic competitors. Such a premium is needed for wool to be an economic proposition. Given the cost of shearing and sorting the message would seem to be even stronger for alpaca.

#### **Contamination and other issues**

The most widespread type of non-wool contamination in yarns and fabric is vegetable matter (VM). The yield, and hence clean price, decreases in proportion to VM content. In addition, there is a 1% to 1.5% penalty for each 1% increase in VM. This is in agreement with the amount of wool lost as the VM is removed in the worsted system.



The next most common contaminants getting through to the fabric are hay-bale twine and wool-pack followed by woven plastic fertiliser or seed bags. These contaminants are either coloured or do not take up wool dyes and become visible faults that need to be mended out of the fabric. It is hard to overestimate the damage done to processors by contamination. In straight monetary terms it probably averages around 50 cents per kg for knitwear producers (24).

Pressure from processors has led to the phasing out of polyethylene wool packs and their replacement by nylon packs as nylon has similar dyeing properties to wool. It has also led to quality management systems in the woolshed whereby good practices must be introduced and maintained for continued certification. Farm dogs are even banned from the woolshed in order to reduce the risk of dark fibre contamination. Contrast this with the reported presence of gravel or screenings present in alpaca because the animals were shorn in the driveway!

In terms of pesticide levels, Australian wool is the cleanest in the world. Wool is perceived as a clean natural product. However, it is important that this image be retained by an on-going pesticide reduction strategy (25). Alpaca will have similar needs.

The effect of long-term storage on greasy wool has been found to be insignificant as witnessed by the lack of penalties for wool that has been stockpiled for more than five years. The wool can be more difficult to open after long-term storage but this can be overcome by temperature and humidity. For scoured wool there has been some evidence that there will be more breakage in processing after pressing and storage but that this can probably be avoided by de-ageing the fibres by elevated temperatures and adequate humidity (26). The biggest dangers from storage on-farm is from moths, theft and water damage (stain and mildew).

#### **Meeting the Market**

Alpaca was only a curiosity in Europe until 1837 when Titus Salt, a Bradford, UK, manufacturer, launched a fabric called "Orleans" (27). Orleans was a weft face cloth woven using a cotton warp and alpaca weft. Its lustrous surface was produced by a finishing process in which the cotton warp was stretched, bringing the weft threads to the face of the fabric. This stiff, lustrous fabric, initially dyed black was a very fashionable dress material from the 1850s to the 1870s. However, in the late 1870s women's fashions shifted to softer, more fluid fabrics and the alpaca trade was ruined.

It might be argued that wool is facing a similar demand crisis because of the move to softer, lighter, easycare casual garments. It has been claimed that the slump in the hand knitting industry from about 1985 was a cause for a drop in demand for alpaca although this is probably also due to the trend to lighter fabrics. As with wool there has been an attempt to widen the market via blends with wool, cotton and silk for both knitwear and woven apparel.

It has been claimed that consumer resistance to buying alpaca stems largely from basic ignorance of the true merits of the fibre, and that this can only be overcome through greater awareness, achieved by suitable promotion. I agree that greater awareness and suitable promotion can lead to increased sales but alpaca growers (just like woolgrowers) need to realise this must be based on products that are attractive and can be differentiated by the consumer. Alpaca is physically and chemically a wool fibre that has a less prominent scale structure and is more slippery but is coarser than Merino wool and has the disadvantage of substantial medullation. Moreover, because of the increased costs of harvesting, it must command a premium in the market place to be economic to produce.

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