

9. Wool Style and Wool Colour Measurement

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Learning objectives

By the end of this topic, you should have:

- an understanding of the subjective nature of traditional wool style
- developed an understanding of the components of style and how these may be objectively measured, and
- an understanding of the impact of style and components of style on early stage processing
- Explain the importance of colour measurement for wool and why there is a wide variation in wool colour
- Explain the specific requirements in wool colour measurement regarding sample preparation, its presentation to the instrument and the calibration procedure
- Differentiate between the base colour and as-is colour of wool

Key terms and concepts

Style, Crimp Frequency, Crimp Definition, Tip Structure, Tip Weathering, Dust Penetration, Dust Colour, Greasy Colour. Filter colorimeter, spectrophotometer, brightness Y, yellowness Y-Z, fleece discolouration, unscourable yellow, reference wool, ceramic tile, wool cell, base colour, as-is colour, ΔY , near infrared reflectance

Introduction to the topic

Style is of particular importance in the superfine end of the market and becomes less important as fibre diameter increases.

This topic describes the visual characteristics used to appraise wool style and examines the relationship between subjective appraisal and objective measurement of wool style. Instruments developed to quantify components of style are described. The importance of components of wool style in processing are quantified and described.

Colour is one of the most important wool properties for processing because it provides the best indication of the 'dyeing potential' of a grower's lot or an export consignment. Wool of poor colour cannot be used to produce a yarn with a light pastel shade, and extremely poor colour may be associated with microbial damage of the fibres. It is necessary to distinguish between the three types of colour associated with wool:

- Greasy colour – the colour of wool in the fleece, before any processing
- Clean colour – the colour of wool after industrial wool scouring (often referred to as 'as-is' colour)
- Base colour – the colour of a wool sample after it has been subjected to a very thorough cleaning treatment, as preparation for colour measurement.

While there is a wide variation in wool colour, even wools of superior colour have a creamy colour in comparison with the bright, white colour, and consistency of colour that is typical of synthetic fibres. These differences place more importance on being able to measure wool colour objectively.

9.1 Subjective appraisal

Traditionally, style has been appraised by wool valuers working for wool brokers, wool exporters or wool industry groups such as AWEX or the former Australian Wool Corporation (AWC). The visual descriptor of style was used for wool valuing, setting of a reserve price, estimating processing potential, aiding communication, quality control (clip inspection), batching of consignments and market intelligence.

A number of visual characteristics are assessed by appraisers of style including, crimp frequency, crimp definition, tip structure, tip weathering, dust penetration, dust colour and greasy colour. As well as assessing the level of these characteristics an assessment of the variability within the display sample is made for each characteristic and better style wool tends to be less variable (more uniform).

Currently, for market reporting purposes the AWEX-ID includes an assessed style grade which takes into account the characteristics listed.

Repeatability of appraisal

An important part of any subjective appraisal system is the repeatability of the appraisal. Any appraisal system is considered better if there is consistency between appraisals by an individual and consistency between individual appraisers.

The introduction of objective measurement in the early 1970's led to the removal of bales from the show floor and the introduction of appraisal of display samples. Many trials were conducted to ensure that appraisal of display samples was similar to appraisal of bales (Working Group 4 1973).

A trial conducted by Champion and Charlton (1991 – unpublished) found a range of within appraiser repeatability from 0.70 to 0.90 for subjective style assessment. The between appraiser repeatability was more variable ranging from 0.26 to 0.83.

9.2 Wool classing

The impact of wool classing on style centres on the ability of the classer to create lines that are uniform and the removal of contaminants from the clip.

Wool classers are required to create lines that are uniform.

Superfine lines are classed on perceived fineness and softness of handle as well as the crimp frequency, the evenness of crimp frequency and the clarity of crimp definition. Tip weathering and dust penetration would tend to downgrade the lines into which fleeces can go.

The AWEX ID system template incorporates a subjective evaluation of wool style as part of the Prime part of the ID. For example in the AWEX ID MF4B the '4' refers to the assessed style of the sale lot.

9.3 Instrumentation

Two types of image analysis instruments capable of objectively measuring individual style characteristics have been developed to a commercial prototype stage. The first instrument, which was developed by CSIRO measured a number of style components including, tiplength (mm), crimp frequency (n/cm), crimp definition (units), wool yellowness (Y-Z tri-stimulus units), wool area (%), dust area (%) and dust colour (X tri-stimulus units). The second instrument was developed by AWTA Ltd and only measures the crimp frequency (n/cm).

CSIRO style instrument

The CSIRO style instrument commercial prototype (Figure 9.1) consists of an automatically controlled system to load and unload staple trays which are bar-coded for identification. The prototype also has an imaging platform that consists of a colour camera, a computer that runs image analysis software and two lighting systems. One lighting system was optimised to provide the high-angle illumination for colour and shape analysis and the second lighting system had low-angle illumination for the crimp analysis.

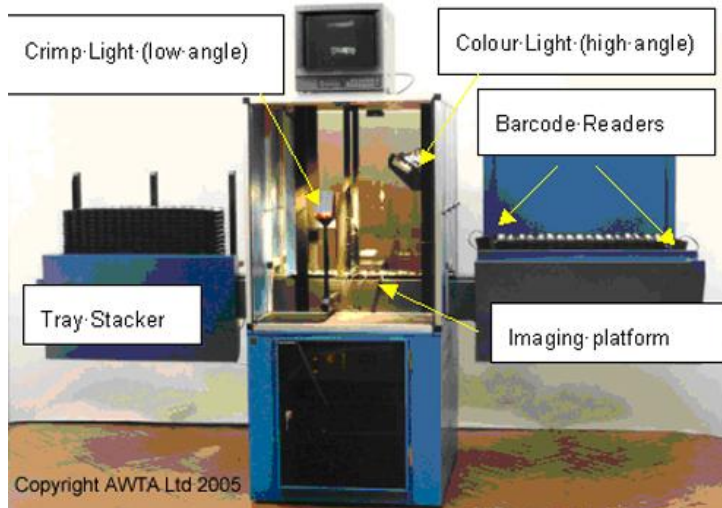


Figure 9.1 Prototype CSIRO style instrument. Source: AWTA Ltd (2006) with permission.

The CSIRO style instrument was designed as a stand alone instrument that used the staples prepared for staple length and staple strength measurement.

AWTA Ltd crimp meter

The crimp meter consists of a near-lightproof enclosure, a light and a camera. The enclosure incorporates doors on each side, and openings for the camera lens and the light source. The prototype was designed as a simple add-on to an ATLAS Instrument (Figure 9.2).

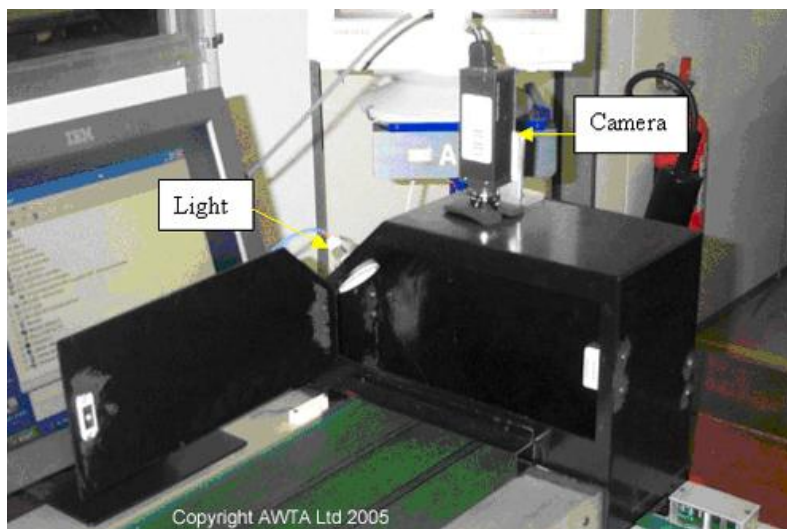


Figure 9.2 Image of the AWTA Ltd. crimp meter prototype. Source: AWTA Ltd (2006) with permission.

The feed belt delivers a staple into the enclosure, where it falls onto the length belt. The camera records an electronic image of the stationary staple before the length belt transports it out of the enclosure and onward to the optical detection (length measurement) system.

9.4 Objective measurement

The objective measurement of components of wool style aims to specify objectively the visual attributes of wool. Essentially the objective measurement has centred on the imaging of the staples prepared for length and strength measurement.

CSIRO style instrument parameters

Table 19.1 summarises the average confidence interval for each of the style attributes measured.

Table 9.1 Summary of CSIRO style instrument confidence interval (CI)* of a single test. Source: AWTA Ltd, CSIRO TFT and The Woolmark Company (2001). Note: The above Confidence Intervals do not include any sampling variance component, so will under estimate the Confidence Interval for a routine Style test.

Trait	Average 95% CI
Staple Length (mm)	±0.5
Tip Length (mm)	±0.3
Crimp Freq. (n/cm)	±0.1
Crimp Definition	±0.1
Wool Yellowness (Y-Z)	±0.2
Wool Area (%)	±2.6
Dust Area (%)	±2.6
Dust Colour (X)	±0.3
Dust Colour (Y)	±0.3
Dust Colour (Z)	±0.3

The data presented in Table 9.2 demonstrates that the variance due to instruments is very small in comparison to both the Between Replicate and Between Staple components.

Table 9.2 Sources of variance for each style component. Source: Hansford et al. (1998).

Source	Staple Length (mm) ²	Tip Length (mm) ²	Crimp Freq. (n/cm) ²	Staple Colour X (unit) ²	Staple Colour Y (unit) ²	Staple Colour Z (unit) ²	Staple Colour Y-Z (unit) ²
Between Instrument	0.067	0.000	0.003	0.032	0.022	0.032	0.000
Between Replicate	5.735	0.385	0.050	0.092	1.151	1.318	0.043
Between Staples	161.330	41.166	16.070	30.228	31.853	28.375	18.544

In 1994, Crowe and Stevens reported work based on using the colour image information collected from staples to derive an objective style grade. This work used a statistical technique known as discriminant analysis that related the measured colour characteristics of individual staples to the assigned style grade of each staple. The resultant database was then used to estimate the style grade of unknown staples. Table 9.3 presents the results of a validation trial involving approximately 300 sale lots.

Table 9.3 Classification contingency table for AWC appraised style grade against computed style grade for Merino combing fleece wool using staple colour information. Source: Crowe and Stevens (1994).

Computed Style Grade	Subjectively Appraised Style Grade			
	Spinners	Best t/m	Good t/m	Average t/m
Spinners	0	0	0	0
Best t/m	14	101	22	0
Good t/m	0	22	94	10
Average t/m	0	0	0	32
% Agreement	0	82	81	76

The data presented in Table 9.3 shows good agreement between computed style grade and AWC appraised style grade for the topmaking styles: best; good; and average. None of the spinners samples were correctly computed. This suggests that colour alone does not aid the discrimination between best topmaking and spinners wool. Perhaps other components such as crimp frequency and crimp definition would improve the discrimination.

AWTA Ltd crimp meter measurement.

Unlike the CSIRO Style Instrument the AWTA Ltd Crimp Meter only measures a single component of style, i.e. staple crimp frequency (n/cm).

Table 9.4 Summary of instrument variances and 95% confidence limits. Source: Crowe (2005).

Within – Instrument Variance (n/cm) ²	Between – Instrument Variance (n/cm) ²	95% Confidence Limit (n/cm)
0.0221	0.0035	0.31

The between instrument variance estimate for the crimp meter is in agreement with the estimate for the CSIRO style instrument. The confidence interval is approximately 3 times the size of the CSIRO style instrument and is possibly a reflection of the sampling variance and the broad range in sale lots used in the crimp meter trial.

9.5 Processing implications of style

Processing studies involving style have included the processing of display samples differing in subjectively appraised style grades. The advent of instrumentation to objectively measure components of style enabled the processing of samples selected to differ in crimp frequency, crimp definition, tip weathering and tip structure. These component trials were generally conducted on display samples that were matched for other raw wool characteristics such as fibre diameter, staple length and staple strength so that the effect of the style component on processing could be determined.

Style grades

The data presented graphically in Figure 9.3 shows that the variation in hauteur, card waste %, scoured yield % and romaine % was often larger within a style grade than the variation between style grades. The style grades compared are subjective style grades. The general trends are for hauteur to increase and card waste to decrease as style grade improves. Trends in scoured yield % and romaine % are less noticeable for the 19µm wool, but for the 22µm wool scoured yield % increases as style grade improves while romaine % decreases.

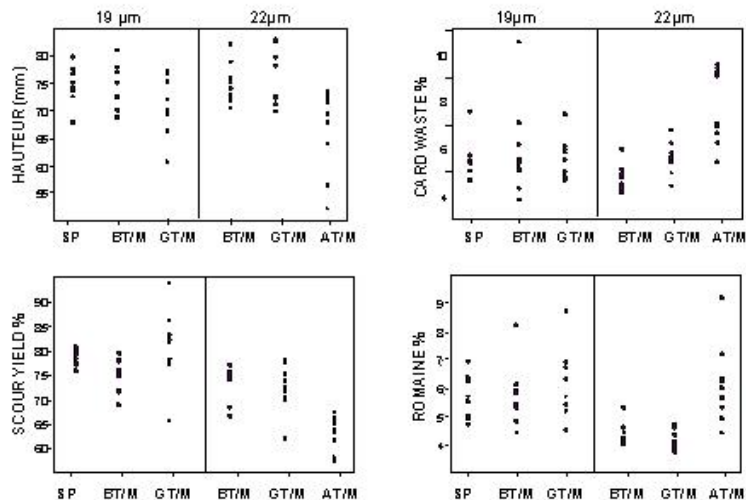


Figure 9.3 Graphical presentation of differences in topmaking parameters both within and between subjective style grades. Source: Stevens and Crowe (1994).

Crimp frequency and crimp definition

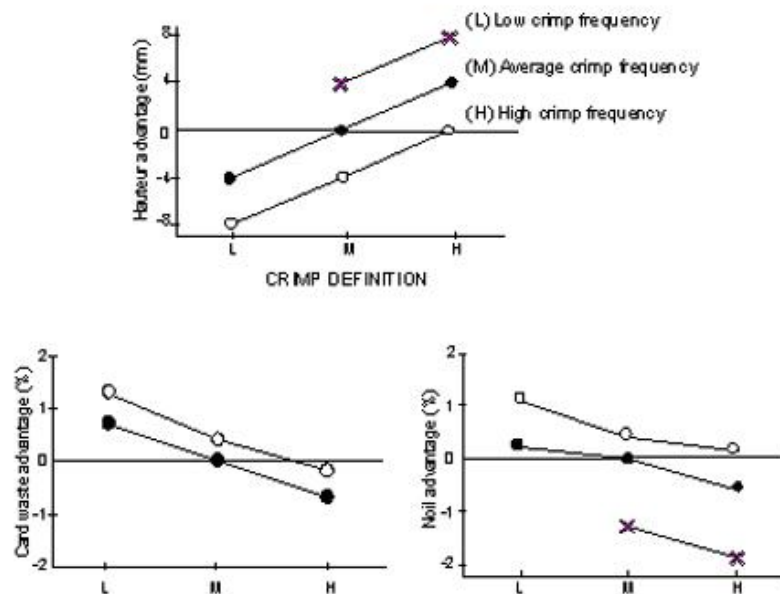


Figure 9.4 Effect of crimp frequency and crimp definition on topmaking parameters. Source: Stevens and Crowe (1994).

The data presented graphically in Figure 9.4 for hauteur, card waste and noil are presented in terms of the advantage in processing achieved by processing wool differing in combinations of crimp frequency and crimp definition. The processing samples were created by purchasing display samples of AWC type 60 B length wool and then sorting the display samples into batches for processing based on visual differences in both crimp frequency and crimp definition. Once the batches were created staples were sampled from each batch and then objective measurements were made for style components on the CSIRO style instrument.

The results indicate that low crimp frequency, high crimp definition wool processes significantly longer, with less card waste and noil than the more traditional high crimp frequency wool.

CSIRO TFT conducted a fibre to fabric project that concluded that crimp frequency affected fabric properties (Haigh & Robinson 2002).

Tip weathering

Table 9.5 Relationship between % weathering and topmaking parameters for 11 fleece pairs matched for fibre diameter, staple length and staple strength, but grown in either a Tablelands or mid-Western NSW Environment. Source: Stevens and Crowe (1994).

Environment	Weathering (%)	Card Waste (%)	Romaine (%)	Hauteur (mm)
Tablelands (NSW)	0.1	5.2	5.4	70
Mid-Western (NSW)	4.0	8.0	7.4	63
Difference	3.9	3.8	2.0	-7

The data presented in Table 9.5 clearly demonstrate the effect of fibre weathering on hauteur, card waste and romaine. All three topmaking parameters are improved by reducing the amount of weathering.

Tip structure

Sale lot display samples were measured for tip length on the CSIRO style instrument and then processed. The display samples were selected from a particular best topmaking C length AWC Type 68 (21.6–22.5 μ m). To minimise the effect of differences in fibre diameter, staple length and staple strength display samples were matched closely for these attributes. Statistical procedures allow the data to be corrected for any remaining small difference in other measured attributes.

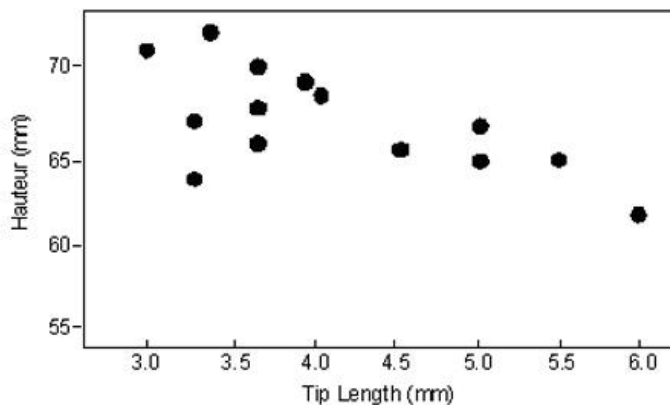


Figure 9.5 Effect of tip length (mm) on the hauteur of AWC type 68 'C' length best topmaking sale lot display samples. Source: Stevens and Crowe (1994).

The results presented in Figure 9.5 demonstrate a reduction in hauteur as tip length increases, but there was no effect on card waste or noil.

9.4 Colour measurement instrumentation

The essential features of a colour measurement instrument are:

- a standard light source
- a prepared specimen is presented in a standard manner to the instrument
- detector(s) of the light reflected off the specimen
- computer and/or electronics to convert detector signals into X, Y and Z values, and other colour parameters.

The early instruments used for colour measurement were tristimulus colorimeters. The operating principle for this type of instrument is shown in Figure 9.6, where a sample of wool is the test specimen. In these relatively simple instruments the light reflected off the test specimen passes through three filters. Just as sunglass lenses permit only a certain range of wavelengths to reach the eye, these filters permit only a limited range of wavelengths in the red, green and blue regions of the spectrum to pass through to light-sensitive detectors. The wavelength responses of the filters are carefully designed to match the colour response functions (\bar{r} , \bar{g} and \bar{b}), and hence the three signals from the detectors correspond to the X, Y and Z values of the wool.

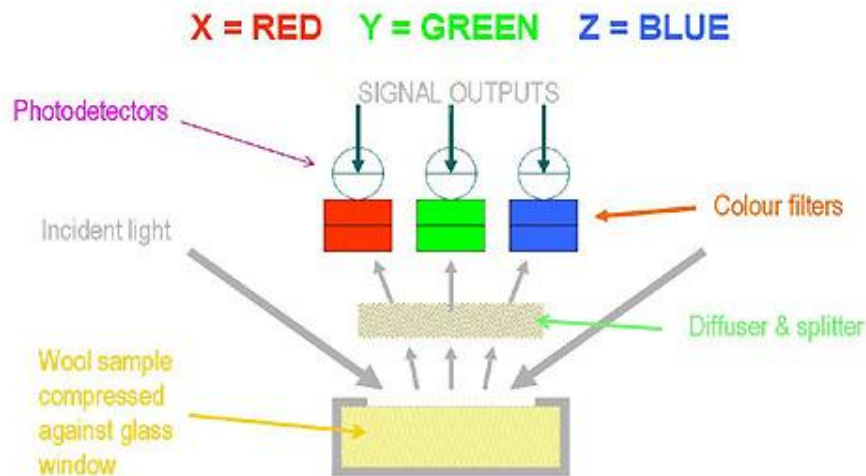


Figure 9.6 Principle of a tristimulus colorimeter.
Source: Canesis Network Ltd, (2006), with permission.

More sophisticated instruments, called colour spectrophotometers, are now mostly used for measuring the colour of wool. The operating principle of a spectrophotometer is shown in Figure 9.7. In this instrument the light reflected off the wool interacts with a reflection grating (http://www.lot-oriel.com/pdf_uk/all/grating_physic.pdf) or similar device.

The grating, which is a series of finely cut lines into a glass plate, splits the light into its component wavelengths, similar to the way in which a prism disperses light into its various colours. The detector senses each of these wavelengths in turn, and its signal is converted into X, Y and Z values by the computer.

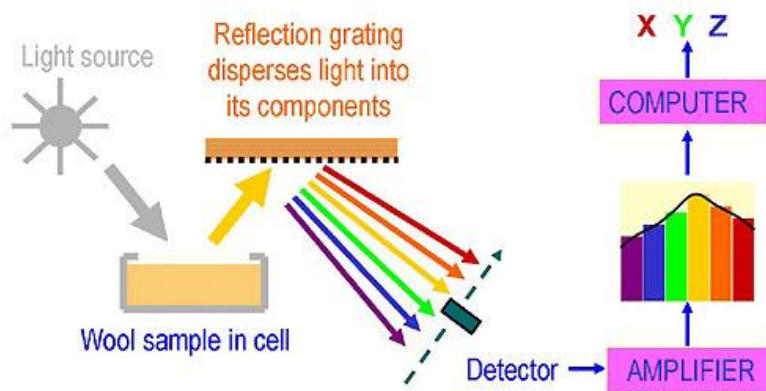


Figure 9.7 Principle of the colour spectrophotometer. Source: Canesis Network Ltd, (2006), with permission.

The international standard for wool colour measurement (IWTO-56-03) specifies a 45/0 geometry.

9.5 Application of colour measurement to wool

The importance of colour in wool

Good wool colour is extremely important for yarns or fabrics that are to be dyed to pale pastel shades. As dyeing is an additive process, it is not possible, without using temporary optical bleaching effects, to produce a shade that is lighter than the original substrate colour (Lindsay 1999a). Additionally, as the natural creamy-yellow component of wool is not stable, pale colours on yellow wools may fade quickly because the strength of the yellow component has been reduced. Poor wool colour may also be an indicator of other processing faults, such as tenderness or wool degradation.

Figure 9.7 shows the effect of different levels of yellowness on the ability to dye a blue shade.

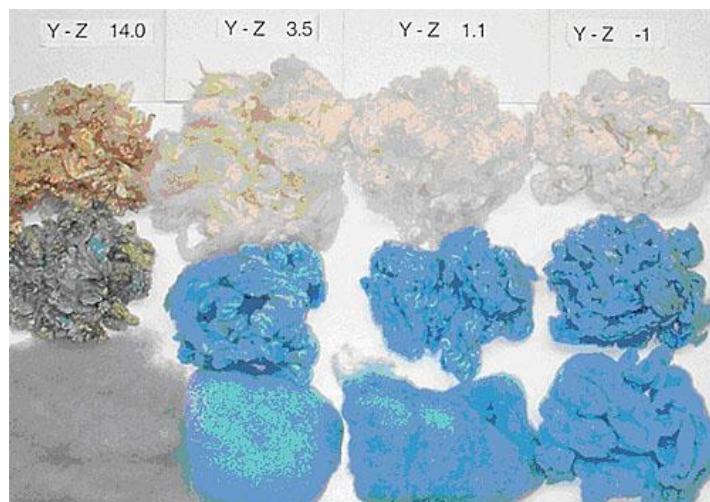


Figure 9.7 Effect of wool yellowness on dyeing quality (top row – undyed wool, middle row – dyed wool, bottom row – dyed and carded wool). Note: the Y-Z values are expressed in $C/2^\circ$ colour space. Source: Wood (2006).

Sources of wool discolouration

The sources of various types of wool discolouration are thoroughly discussed by Henderson (Henderson 1968). The most general source of discolouration is diffuse yellowness which is most apparent in crossbred wools shorn late in the season and which have grown in warm,

moist conditions. Although this discolouration is largely scourable, its presence tends to obscure the subjective assessment of the clean wool colour. Where long-woolled sheep are subjected to prolonged periods of warm, moist conditions after their fleece has become thoroughly wetted, an unscourable yellowness called canary stain may develop. This condition, which may appear as either discrete bands in the fleece or in extreme cases spread throughout the fleece, is particularly prevalent in cotted wools. Other forms of discolouration are caused by bacterial action within the fleece. Most scour out although others are permanent and in a few cases may also damage the fibre.

Yellowing of the fleece can be minimised in New Zealand by shearing in late winter/early spring, before the onset of moist warm conditions cause yellowness to develop. Figure 9.8 shows the variation in yellowness throughout the year.

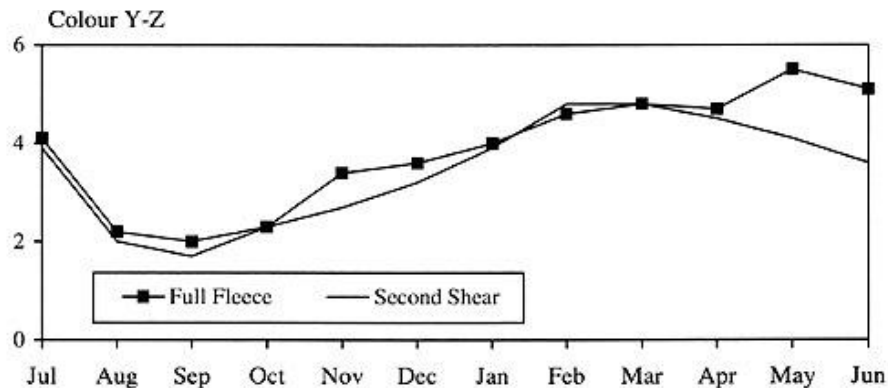


Figure 9.8 Variation in wool yellowness throughout the growing season.
Source: Wools of New Zealand.

Researchers at Lincoln University have developed a predictive test for the propensity of wool to yellow in the fleece. There is some evidence that propensity to yellowing is genetically based and can therefore be reduced in a flock by selection, based on the results of the predictive test (Reid 1998).

Wool colour can also be affected by natural staining. Although faecal material is usually scourable, unscourable breakdown products of pigments in grass may affect the colourfastness of some pastel shades to sunlight. Urine stains are unscourable and wool tends to be permanently discoloured if it becomes very muddy.

The high correlation between base colour of greasy merino wool and the corresponding colour in the top, especially with respect to yellowness, has been demonstrated (Mahar and Osborne 1996).

Colour stability

Greasy wool will also eventually discolour in storage over a timeframe of 6-12 months; the more yellow the original colour, the sooner and more marked will be the change.

Another colour stability issue, especially with carpet wools, and other wool interior textiles subjected to sunlight, is the problem of photobleaching. The ultraviolet component in sunlight tends to rapidly bleach the creamy colour and this causes a shift in the shade of a dyed product. A time scale of just a few days is involved. However, the Lanalbin APB technology (http://www.canesis.com/Brochures/Product_Lanalbin.pdf), developed by Canesis, eliminates this problem by applying an agent to the fibre that photoyellows at the same rate that the wool substrate photobleaches. The net result is a stable colour for the product even when subjected to prolonged, intense sunlight.

Commercial wool colour measurement

While the colour test was rapidly adopted in New Zealand for the commercial testing of greasy wools prior to sale, the uptake in Australia has been lower. This is largely because there is a

widespread belief that the bulk of Australian wool is white and bright and a test result would add little value. Certainly, a typical merino fleece is generally whiter and brighter than a typical crossbred fleece. Furthermore, most Australian wool is produced in drier regions where deterioration in wool colour due to humidity and moisture is less prevalent. As a result, the demand for colour testing in Australia has actually fallen during the past decade, with colour testing of sale lots dropping from 20% in 1997/98 (Lindsay 1999b) to around 2% in 2000/2001 (Wood 2002). According to the most recently available data from the Australian Wool Testing Authority (<http://www.awta.com.au/Publications/Statistics/Statistics.htm>) the test is now being requested on less than 1% of sale lots.

However, the view that the test is unimportant in Australia is only partly correct because considerable quantities of wool typed as light, medium and heavy unscourable colour are produced. These wools are identified based on visual assessment of the greasy wool. However, the colour of greasy wool is a poor indicator of the colour of the same wool after it has been scoured. This poor correlation is due to the effects of wool grease and dust on colour, both of which are removed by scouring.

On the other hand, colour measurement on wool is firmly entrenched in New Zealand, with close to 100% utilisation on greasy auction lots, because it provides vital information for wool trading purposes. The wool clip shows a wide variation in colour, from near-white merino to highly discoloured oddments. Colour varies through the season (see Figure 9.7) and from location to location because of climatic differences. It will vary from season to season depending on the weather, and breed, environment, shearing time and on-farm practices also have an influence.

Sample preparation

Samples of wool for commercial testing are supplied as core samples, mostly being extracted in a broker's store or a wool scour. To obtain consistent, meaningful results it is essential that the specimen of wool presented for colour measurement is in the cleanest, most homogeneous possible state. The results obtained from such a specimen define the 'base colour' of the wool. If scoured wool is tested without a further cleaning treatment then the results define the 'as-is colour' of the wool. Greasy wool is never tested for colour without a thorough prior cleaning treatment.

The IWTO test method does not prescribe the procedure for cleaning the wool sample, instead it states "the essential requirements for sample preparation for colour measurement are that the wool be cleaned of contaminants (e.g. grease, dirt, vegetable matter etc.), well-blended and conditioned. The procedures used in sample preparation should be such that the base colour of the wool is not altered" (IWTO-56-03). To meet these requirements the test houses have machines for preparing samples that are:

- free of wool grease, suint and dirt
- thoroughly blended
- randomised (with respect to fibre orientation)
- free of vegetable matter and other particulate contaminants
- open (as opposed to being entangled).

A sample destined for colour measurement is usually in the form of cores. It is subjected to agitated scouring in hot water and detergent, hydroextracted then dried. This is followed by opening of the clumps of fibre, removal of particulate contaminants and the mixing of the fibres by a mechanical carding action. The IWTO test method prescribes the Shirley Analyser (<http://www.sdlatlas.com/html/f102a.html>) machine.

The colour of wool can be influenced by many factors during sample preparation:

- Quality of the water used for scouring the samples
- Drying – prolonged drying at 105°C can yellow some wools and should be avoided
- Air quality in the laboratory – during drying and conditioning large volumes of air are passed over the wool. If this air contains dust this may become trapped in the wool sample

- Shirley Analysing – the perforated cage of the machine and any surfaces that come into contact with the wool must be checked to ensure that contaminants are not transferred to the sample
- Fluorescent lighting – extended exposure, especially in close proximity, can change the colour of the wool.

While colour results are less influenced by wool regain variations than other parameters, wool prepared for colour measurement is usually conditioned in a standard atmosphere for a fixed period.

Interpretation of wool colour results

The colour spectrophotometer delivers results as tristimulus values X, Y and Z. While all three are quoted on a wool test certificate, in practice only two parameters are necessary. They are:

Y which is closely related to the lightness of the wool and is often called 'brightness', and

Y – Z which is related to the 'yellowness' of the wool.

The wool industry has found these two parameters form a necessary and sufficient set to specify the colour of wool for trading purposes.

While the higher the Y value the better the colour of the wool (bright instead of dull and dingy), the Y-Z value should be as low as possible (light cream as opposed to yellow or even darker).

In the more than 25 years since the colour testing of wool was introduced, the international wool textile industry (i.e. growers, scourers, brokers, wool buyers, spinners and dyers) has become confident and experienced in using the test results expressed in terms of Y and Y-Z.

The recent changes to the wool colour test outlined previously mean that shifts in these parameters have been inevitable; i.e. Y has increased by 4-6 units and Z has reduced by 2-5 units so that Y-Z has increased by approximately 8-9 units (see http://www.wooltesting.sgs.com/iwto_circular_58_02.pdf). As a guide, Table 9.6 shows how brightness Y and yellowness Y-Z have changed for wools of various colours.

Table 9.6 Comparison of colour results for different wool types. Source NZWTA.

Level	Brightness Y		Level	Yellowness Y – Z	
	D65/10	C/2		D65/10	C/2
Very bright	>70	>66	Very white	<9	<-2
Bright	68-70	64-66	White	9-10.5	-2 – 0
Average	64-68	60-64	Slightly creamy	10.5-12.5	0-3
Slightly dingy	59-64	56-60	Creamy	12.5-14.5	3-6
Dingy	<59	<56	Quite yellow	14.5-16	6-8
			Heavily stained/yellow	>16	>8

It must be noted that the Y and Y-Z results for good colour wools are quite different for fine and coarse wools. While premium quality Merino wools may often be described as bright and white, the best of the Romney wools do not often score better than the average brightness and creamy yellowness level.

To assist the international wool industry with the management of these significant shifts in colour results, conversion formulae (or baremes) have been provided in IWTO 56-03.

Base colour and 'as-is' colour

The base colour of wool is the result obtained by applying the IWTO test (in a test house) to a sample of wool that has been cleaned as thoroughly as possible. The 'as-is' colour is the result that might be obtained in a wool scour where a sample taken from the dryer is measured without any further cleaning. Commercially scoured wool is not perfectly clean but always

contains some contaminating dirt. Therefore, it is inevitable that the as-is colour of a wool will be inferior to its base colour. The difference in the Y tristimulus values between two samples of the same wool (one prepared as for the base colour test and the other taken directly from the scour) provides a measure of the effectiveness of commercial scouring (along with residual grease content result). The parameter of interest, ΔY , is defined as:

$$\Delta Y = Y_{\text{base}} - Y_{\text{as-is}}$$

ΔY is strongly influenced by the scouring conditions, for example, the concentration of detergent (Figure 9.9) and the flowdown (water discharge) rate (Figure 9.10). A close correlation between ΔY and the level of residual grease on the wool is evident.

The Canesis Glacial (<http://www.canesis.com/Brochures/Glacial.pdf>) process for the scouring of wool optimises the treatment conditions so that the whitest, brightest and cleanest wool possible is delivered, and ΔY becomes as small as practicable.

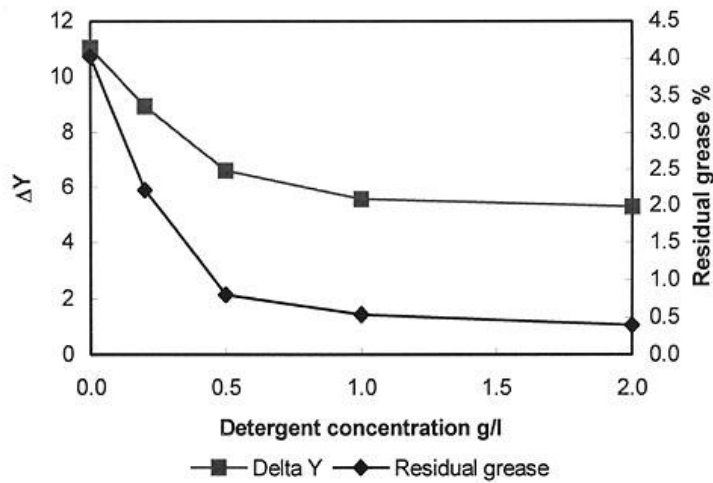


Figure 9.9 Effect of detergent concentration on ΔY . Source: Wood (2006).

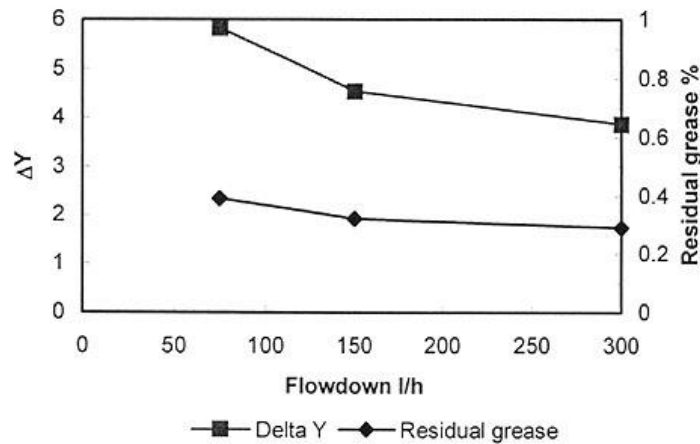


Figure 9.10 Effect of flowdown on ΔY . Source: Wood (2006).

9.6 NIR instrumentation for wool colour measurement

Near infrared reflectance (NIR) instruments are able to measure the tristimulus values for scoured wool (Hammersley and Townsend 1994). They mostly use a diffraction grating that disperses light into its component wavelengths (Figure 9.11) for detection by infrared and visible light sensors. Unlike earlier NIR instruments, which were filter-based, the modern instruments are not restricted to the invisible near infrared region but also can operate in the visible region of the electromagnetic spectrum.

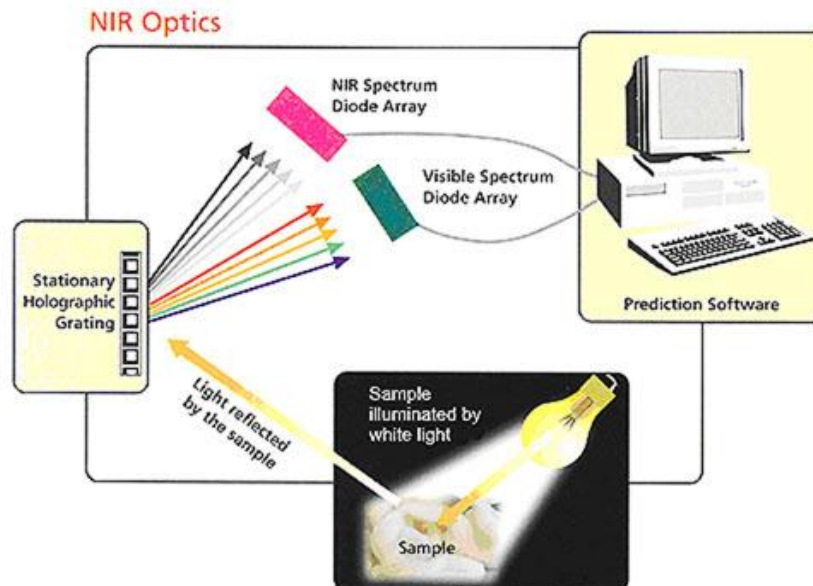


Figure 9.11 Principle of wool colour measurement using NIR. Source: Walls (2002).

Unlike colorimeters and spectrophotometers, NIR instruments measure colour indirectly, i.e. from the influence of the features of interest (e.g. moisture content, residual grease content, etc) on the reflectance of radiation in the near infrared region of the electromagnetic spectrum. Consequently, these instruments must be calibrated using wools with a wide range of properties that encompass the range which will be measured in everyday use. For example, to calibrate a NIR instrument for colour measurement, numerous wool samples which have been measured by the conventional IWTO method for colour and which span the range of Y and Y-Z are required.

Most New Zealand wool scours have NIR technology installed to measure on a bale-by-bale basis the moisture content, residual grease and colour of the wool leaving the scouring line. The *Canesis*-developed NIRASPEC-S system is the most advanced online instrument for the quality control of scoured wool in the world (Figure 9.12).



Figure 9.12 NiraSpec instrument in a wool scour, showing the sample delivery system and computer. Source: Wood (2006).

Core samples are sent pneumatically to the instrument for measurement and then discharged into a receptacle, without requiring any handling by operators. The suite of test results, which include estimates of base colour and as-is colour, are displayed on the computer monitor within one minute. The availability of such comprehensive information in a rapid manner enables adjustments to optimise the various operations of the scour to be made as required.

Readings

The following readings are available on web learning management systems

1. AWTA Ltd, CSIRO TFT, The Woolmark Company, 2001, 'Final Report on the Performance of the Style Instruments,' *Proceedings. of IWTO, Technology and Standards Committee*, Nice, Report No. RWG03.
2. Hansford, K.A. Higgerson, G.H., Humphries, W., Tchen, T., Tischler, C., Brown, G.H. and Morgan, P.D. 1998, 'The Variation in and Relationships between the Objectively Measured Components of Greasy Wool Style,' *Proceedings. of IWTO, Technology and Standards Committee*, Dresden, Report No. 23.
3. Jackson, N. and Rottenbury, R.A. 1994, 'Style Metrology,' *Proceedings. of WoolSpec '94, Seminar on Specification of Australian Wool and its Implications for Marketing and Processing*. R.J. Rottenbury, K.A. Hansford and J.P. Scanlan (eds.).
4. Baxter, P. 2001, Stability of wool colour, Massey Wool Association Conference: Colour, the ABC of XYZ.
5. Harold, R.W. 2001, An introduction to appearance analysis, second sight, Graphic Arts Technical Foundation, No. 84.
6. Wood, E.J. The Basics of Wool Colour Measurement, Canesis Network Ltd.

Summary

Summary Slides are available on web learning management systems

This topic has attempted to show how measurement of style components has evolved from the subjective appraisal of style grade. The development of two instruments is highlighted. These instruments measure components of style such as Crimp Frequency, Dust Colour, Tip Shape. The processing performance of different style grades and a number of style components is discussed.

Colour is one of the most important wool properties because it provides the best indication of the 'dyeing potential' of a grower's lot or an export consignment. Wool of poor colour cannot be used to produce a yarn with a light pastel shade, and extremely poor colour may be associated with microbial damage of the fibres.

While a range of illuminants and instrument geometries have been used in various colour applications over the years, the wool industry has now standardised on the D65 illuminant with a viewing angle of 10 degrees. The key tristimulus values reported are Y (brightness) and Y-Z (yellowness).

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Glossary of terms

Absorption	Dissipation of the energy of electromagnetic waves into another form as it interacts with matter
As-is colour	The colour results obtained from scoured wool, which has received no further cleaning before testing
Base colour	The colour results obtained from a wool in its cleanest possible form
Brightness (wool)	The tristimulus value Y is used to represent the brightness of wool (i.e. bright as opposed to dul/dingy)
CIE tristimulus values	Amounts of the three components, designated as X, Y and Z, necessary in a 3 colour mixture to match a colour
CIE chromaticity coordinates	x and y values that specify the location of colour within the CIE chromaticity diagram
Colorant	Dye, pigment or other agent used to impart colour to a material
Colour matching	Procedure for establishing visual equivalence of two colours
Colour matching functions	Relative amounts of three additive primaries required to match each wavelength of light – usually refers to CIE Standard Observer
Colour space	A three-dimensional geometrical representation of colours that can be seen
Colorimeter	An optical measurement instrument that responds to colour similarly to the human eye by filtering light into its dominant

	regions of red, green and blue
Discolouration	The departure of wool from its ideal colour (white or light cream) due to microbial action, soiling or staining
Electromagnetic spectrum	The wide band of electromagnetic waves, as measured by wavelength Only e-m waves in the range 380 – 720 nm are visible, producing light
IWTO	International Wool Textile Organisation, the international body that oversees the trading of wool, including the development of appropriate test methods
Near infrared reflectance	The technique of measuring the amount of electromagnetic radiation that is reflected by a material in the near infrared region
Opponent colours	The three pairs of opponent colours – black/white, red/green and yellow/blue can be assigned mutually perpendicular axes which define a three dimensional colour space
Crimp Frequency	See Glossary for Topic 1
Crimp Definition	See Glossary for Topic 1
Dust Colour	Traditionally, wool with red dust has been considered a problem to scour and dust colour has been associated with other environmental factors that impact on the visual assessment of Style
Dust Penetration	The degree to which dust has moved down the staple from the tip. It is often a precondition for tip weathering, i.e. wool where the dust has penetrated further down the staple is more likely to also suffer from tip weathering
Greasy Colour	An assessment of the underlying colour of the greasy wool. Poorer Style wool is associated with a creamier or yellow colour. The best merino wool has a soft pearly white greasy colour
Repeatability	A statistical measure of the consistency between measurements or appraisals of the same sample
Style	Refers to a collection of visual characteristics of fleeces including tip structure, tip weathering, dust penetration, crimp frequency, crimp definition, greasy wool colour, and the presence of any fleece abnormality such as mycotic dermatitis and uniformity of these characteristics as well as other raw wool characteristics within the sale lot
Tip Structure	Refers to the shape of the tip region of staples. A square 'blocky' tip is associated with uniform fibre length distribution, while a 'pointy' or 'tippy' tip is associated with a very variable fibre length distribution within the staple
Tip Weathering	Refers to the degradation of the staple tip by the absorption of ultra violet light from the sun. It is often associated with wool where the dust has penetrated down the staple