8. Yield

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Learning objectives

By the end of this topic, you should have:

- an understanding of the importance of Yield to the textile manufacturer
- an understanding of the processes involved in producing an estimate for Yield
- knowledge of the components which lead to estimates of Yield
- knowledge of the different types of Yield estimates available, and the markets in which they most commonly apply, and
- an understanding of the requirements in providing an estimate of Yield on an IWTO Test Certificate

Key terms and concepts

Yield, Top and Noil, tear ratio, carbonising, consignment, card sliver, Vegetable Matter Base, Spinning Quality, condition, processing allowance, sound-combing wool.

Introduction to the topic

Presale testing for Yield has been an integral part of the Australian wool selling system since the introduction of Sale by Sample in July, 1972. Today virtually all Australian wool is tested for Yield (and Mean Fibre Diameter), irrespective of the method of marketing, and is sold to the processor on test results. In fact, failure to provide presale test information results in reduced competition and in severe price penalties.

This topic focuses on the determination of Yield as applied to the trading and processing of wool, and the considerations inherent in this determination, by progressing the reader through the following areas:

- Purpose of Measurement
- Components of Yield
- Principles
- Equipment
- Procedures
- Standards
- Derived Yield Estimates, and
- Yield Testing of Fleeces.

8.1 Purpose of measurement

The value of greasy wool is significantly determined by its Yield. The percentage Yield of clean scoured wool (greasy wool minus its grease, wax, sweat, dirt and plant material) is the product processed by the manufacturer. As much of the greasy weight consists of these impurities, the proportion must be known so that the price per kilogram in the grease, that will correspond with the clean-scoured cost, can be fixed.

The greasy value is affected by the amount of extraneous matter present in the wool. The higher the Yield, or the greater the percentage of pure wool in the consignment, the higher the greasy value will be.

The wool processor is vitally interested in the amount of usable wool fibre present in a consignment. From the choice of International Wool Textile Organisation (IWTO) Commercial Yields available (refer section 5.7 *'Derived Yield Estimates'*) the processor is able to utilise the one which is most appropriate for their process in predicting the processing Yield of particular consignments of wool.

During commercial combing, consideration must be given to the fact that variation in processing losses between mills can lead to combing results showing under or over Yields in comparison to that predicted by the core test results. While it is normal for individual Yield results to differ from these core test predictions, over a time a mill's combing results on average will normally be consistent and show an over / under Yield within one percent of the weighted average of the core test Yield.

The widespread acceptance today of Yield by a core test has come about because the methods and the calculations are capable of predicting the actual processing performance of the wool. This has given confidence to the parties buying and selling wool.

The Australian Wool Testing Authority Limited (AWTA) has collected mill processing information on many lots over a number of years. In brief, the findings are as follows:

- On average, the processing allowances used in the core test top and noil Yield calculations reflect actual mill performance on most wools
- Specific wool types, particularly wools with a high vegetable matter content, tend to process more severely than the core test Yield will indicate
- Individual mills often perform differently to each other in relation to core test, but are generally consistent in their own performance, i.e., one mill may consistently process Yields 0.5% greater than core test, another mill consistently 0.5% less.

While it would be ideal for all core test results to reflect accurately all mill results, it is no real disadvantage in trading, provided that the traders are confident in the repeatability of both the core test laboratory's performance and the performance of the mill in which the wool is to be processed. Because the core test Yield acts as the bench mark, and as both parties to the transactions agree on the use of core test to specify Yield, the trading price can be agreed upon between the buyer and the seller.

Yield is an interesting measurement as there are valid objections to very high values as well as to very low values. A certain amount of grease and wax is needed to protect both wool and skin. A very high Yield is often associated with a weather damaged tip to the fleece. This is particularly noticeable in wool from the back where the damage may extend well down the staple. This weakened tip is lost as "noil" during the combing process giving a reduced Yield in manufacture. Fleece rot is another form of weather damage which is sometimes more pronounced in sheep with high yielding fleeces.

8.2 Components of yield

The factors which influence Yield are nearly the same as those taken into account when assessing type. For example, sound-combing wool, which is bulky and stylish with good colour, and free or nearly free from vegetable matter, would be expected to Yield a high percentage of commercial fibre. Conversely, inferior combing wool which is irregular in length, wasty tip, is thin, has heavy dust and burr, would have a much lower Yield of commercial fibre.
Factors contributing to the estimation of Yield are provided below:

Wool base
Wool Base is the oven dry weight of wool fibre, free from all impurities, such as ash, grease, vegetable matter and other contaminants, expressed as a percentage of the weight of the sample.

Spinning quality
Yield varies with spinning quality. For example, if two wools differed only in their count, the coarser wool would have the higher Yield. The reason is that the coarser wool has a smaller surface area per kilogram than the finer wool. This allows the finer wool to carry more grease and other impurities, known as condition.

Wool grease
Wool Grease is natural fat contained in raw or greasy wool. Greasy wool (sometimes referred to as 'yolky' wool) will not Yield as well as a comparatively light conditioned, evenly nourished wool. When fleeces carry heavy condition, there is a decline in both type and Yield.

Length
Length plays an important part in determining Yield. Merino wools of 50 millimetres in length would have a larger proportion of tip than those of 75 millimetres, taking weight for weight. The yolk in the tip of the staple retains the soil particles, lowering the Yield. In a comparison of wools differing only in length, the longer wool should Yield more than the shorter wool.

Density
Generally, the denser the wool, the lighter the condition. In dense wool, the fibres grow very close together so with many more fibres per square unit of skin it is more difficult for dust and dirt to penetrate the fleece. When the wool is thin or poorly nourished, the dust usually penetrates through the wool to the skin.

Mineral matter
Yield is affected by the quantity of earthy matter – sand, dust, etc. that is present in the wool. Therefore, it is important to know the comparative weights of earthy materials when estimating Yield. Some earthy materials are heavier than others, for example, the heaviest found in wool, is sea sand, followed by red sand, then dust and loam.

Vegetable matter
To the processor, vegetable matter (such as grass seed and burr) forms the most troublesome of all the extraneous materials found in wool and such contamination reduces the Yield of all wool types. In appraising the best types of combing fleece and the best skirtings (Spinners types), separate categories are recognised for those types which are free, practically free, or nearly free from vegetable fault. In the lower types of combing wool, further distinctions are made for types which have a light (up to 3 per cent), medium (3 to 6 per cent) or heavy (6 to 12 per cent) degree of vegetable fault.

The limit of vegetable fault, for a combing type of wool, is about 12 per cent of the wool's greasy weight. Wool carrying seed or burr in excess of this percentage is classed as a type requiring the carbonising process. The heaviest component is Noogoora burr, followed by Bathurst burr, Trefoil burr and grass seeds.

The type of fault is extremely important because some vegetable fault is more difficult to remove than others. An example is shive, which is extremely difficult to remove, even if only in small quantities. The fine particles tend to remain in the wool after carding and combing. Thus, most 'shivy' wools have to be carbonised.

Colour
Wool of a good colour produces a better Yield than wool with a greasy black tip.

Water washed appearance
When sheep have been run in country with a high rainfall, most of the yolk is washed out of the wool, so the wool is light in condition.

8.3 Principles

In testing greasy wool samples for Yield, it is necessary to perform the full test procedure on more than one subsample in order to increase the precision associated with the measurement.

According to the procedures set out in IWTO-19-03, a representative sample of raw wool is obtained from each bale in the lot by coring methods. Representative subsamples of the cores are weighed, scoured, dried and re-weighed. Test specimens are then taken from each scoured subsample for the separate determination of Vegetable Matter (which can be expressed as

Vegetable Matter Base), Ash and Ethyl Alcohol Extractives. The percentage of these non-wool constituents found are used to determine the dry mass of wool fibres free from all impurities which, when expressed as a percentage of the mass of the sample, is the Wool Base. The Wool Base is then converted to a % Yield by applying a standard regain and processing allowance (where applicable) that is expected to be produced when a delivery of raw wool is processed.

Principles associated with test results

All IWTO Test Certificates for Yield and IWTO Combined Certificates for Yield must show the following:

- Wool Base % to 2 decimal places, and
- VM Base (including % Hard Heads and Twigs Base) % to 1 decimal place.

In addition, various commercial yields may be shown. For IWTO Test Certificates these yields are calculated from the tested certified values given above using standard conditions and average processing allowances defined in section 5.7 *'Derived Yield Estimates'*. For IWTO Combined Certificates (and Combined Certificates By Subtraction) the commercial Yields shall be obtained from the sum (difference) of the commercial Yield weights of the component parts and expressed as a percentage of the sum (difference) of the nett greasy weights of the component parts.

For Raw Wool, these commercial Yields are shown on the certificate as:

- IWTO Clean Wool Content, % and weight
- IWTO Scoured Yield at R% Regain, % and weight
- Japanese Clean Scoured Yield, % and weight, and
- ASTM Clean Wool Fibre Present, % and weight.

For Greasy and Slipe Wools only, these commercial Yields are:

- Theoretical Top and Noil Yield (specified combing method and Total Fatty Matter (TFM) content), % and weight
- Estimated Commercial Top and Noil Yield (specified combing method and TFM content), % and weight
- Theoretical Card Sliver Yield, % and weight
- Estimated Commercial Card Sliver Yield, % and weight, and
- Australian Carbonising Yield, % and weight.

It should also be noted that all IWTO Combined Certificates for Yield must show the highest and lowest Vegetable Matter Base of the individual Test Certificates forming the Combined Certificates.

In addition, if contracting parties agree to use non-standard TFM contents, the general equation for the calculation of Theoretical Top and Noil Yields, which is defined in section 5.7 '*Derived Yield Estimates*', may be used to determine the appropriate conversion factor for conversion of Wool Base into a Theoretical Top and Noil Yield, however it is essential that the contracting parties specify:

- Total Fatty Matter Contents of Top (F%) and Noil (f%)
- Top and Noil Regains (respectively R% and r%), and
- Tear, t (if standard Tear of 8:1 is not used).

Guidelines for the calculation and reporting of results

A number of guidelines are put in place to ensure that repeatable values for certified commercial Yield when using the Wool Base and Vegetable Matter Base are derived according to IWTO-19. These are as follows:

- All calculation equipment and procedures used to calculate results must be capable of handling numbers of 8 significant digits without truncation
- Except as required by these guidelines, no number used shall be truncated or rounded for any purpose other than to remain within the capacity of the equipment, and any such truncation of rounding must retain the maximum possible number of digits

- When rounding, the last digit to be retained shall be left unchanged unless the next succeeding digit is 5 or more, in which case the value of the last retained digit is increased by 1, and
- As required by the IWTO Core test Regulations, Commercial Yields must be reported to 1 decimal place, and Commercial Yield Mass must be reported to the nearest whole kilogram.

8.4 Equipment

The following equipment is required in determining the Yield from a Core test, as documented in the IWTO Core test Regulations and in IWTO-19-03.

Coring

Balance – capable of weighing an approximate 200kg bale of wool. (According to the IWTO Core test Regulations, every bale of wool in the lot is weighed to ensure that no change in the bale mass occurs between weighing and sampling.)
Coring machine – equipment which uses hydraulic power to drive one or more pressure coring tubes into a bale of wool, so that the tube reaches at least 93% of the length of the bale. Cores are automatically ejected from the tube
Coring tube – a tube of circular cross-section, which is equipped with a sharpened, replaceable tip. The tip enables the tube to penetrate a bale of raw wool without rotation, remove a cylindrically shaped portion of the wool and retain it without change in material or moisture content.

As mentioned above, when it is part of a coring machine, the coring tube must penetrate at least 93% of the length of the bale. When operated manually though, the tube must penetrate at least 47% of the length of the bale, and the bale is cored from both ends to achieve the minimum 93% penetration.

Blending and subsampling

The guidelines set out in IWTO-19 stipulate that *'A number of methods are applicable for preparation of the sample and selection of subsamples*.' For the purposes of this topic however, the equipment used for blending and subsampling at AWTA Ltd are documented.
Balance – capable of weighing to 0.1g
Blending tub – large plastic tub used for holding the wool sample
Air Blender – an air operated lid that seals itself onto the top of the blending tub and then injects compressed air. This blends the wool sample inside the tub.

Scouring

The following equipment are defined as '*suitable*' according to the guidelines set out in IWTO-19.
Scouring bowl – of 30 to 50 litres capacity, with an attached drain board. The lower portion of the bowl is in the shape of an inverted pyramid or cone that is connected to a sliding disc valve and a short length of drain pipe. The drain pipe is centred over a 75µm (200 mesh per inch) sieve, 120 to 200mm in diameter, supported in a catch basin
Two perforated plates – designed to fit closely at the bottom of the scour bowl above the valve and drain pipe. One is a coarse plate with 1 to 2mm openings, and the other plate is similar but covered on its upper surface with 150µm (100 mesh per inch) woven wire cloth
Sieve – 120 to 200mm in diameter, with 75µm (200 mesh per inch) wire screen, to place under the drain pipe of the bowl
Thermostatically controlled device – capable of delivering water to the scouring bowl at a desired temperature with a tolerance of ±3°C
Spray head – with a flexible connection, for use in rinsing
Flotation jar – a glass or transparent plastic vessel or 1 or 2 litres capacity, approximately 200mm tall, for separating by flotation the short wool fibres retained by the 75µm sieve from associated sand and other heavy impurities
Centrifuge – for the removal of excess water from the scoured sample before drying in an oven
Drying can – with bottom formed from 150µm (100 mesh) wire screen, supported by a perforated plate. The dimensions of the can must be such that the can is capable of containing the scoured sample and fitting into the centrifuge.

Drying

Wool drier – capable of forcing hot air through the samples and removing the moisture. The drier must be capable of delivering air at 105°±2°C
Balance – capable of weighing a can containing a dry subsample to 0.01g, and appropriate shielding of the balance
Suitable psychrometer – to monitor temperature and relative humidity

Ash determination

Balances – one for determining the mass of the test specimen to 0.01g and another for determining the weight of residue to 0.001g
Crucible – to hold a 10g subsample of scoured wool, and capable of firing at 750°±50°C
Gas burners – to be used for charring the test specimen prior to ashing
Furnace – a ventilated ashing furnace, to be capable of maintaining a temperature of 750°±50°C
Desiccator – for cooling the crucible and residue
The IWTO Standard has been amended to allow the estimation of Ash by Near Infrared Reflectance (NIR). This is a non destructive test, but the NIR instrument must be calibrated using the conventional method as a reference. A description of the equipment is provided in the section Grease Determination.

VMB and TAI determination

Balances - one for weighing the test specimens to 0.01g; and one capable of determining the mass of alkali insoluble impurities and mineral ash to 0.001g
Alkali resistant container – of not less than 2 litres capacity
Hotplate – or other suitable heating apparatus for heating the alkali to boiling point
Alkali resistant sieve – these are round plastic sieves, having nominal aperture size from 355 – 425µm for filtering the TAI from the dissolved sample. A suitable alkali resistant tray in which to stand the sieve while washing the insoluble residue is also required so that:

- at least 20mm of liquid constantly remains in the sieve during spraying, and
- the sieve mesh is clear of the floor of the tray by at least 7mm, to allow the rinse liquid to leave the sieve through its mesh base and finally to overflow the sides of the tray.

Spray nozzle – to be fitted above the tray, and must be adjusted so that the fine spray jets cover the surface of the liquid inside the sieve evenly, with minimal agitation of the vegetable matter
Tared crucible – of accurately known mass after firing at 750±50°C. (The crucible is used for determining the mineral matter content of the residue, known as *VM Ash.*)
Drier – capable of drying the residue in air at 110±2°C without any loss of material
note: within AWTA Ltd, the Dissolving process is undertaken by an automatic dissolver which dispenses hot caustic soda directly into the bowls. (This procedure is described fully in Section 5.5 'Procedures/Vegetable Matter Content Analysis'.)

Grease determination

The equipment associated with two suitable methods are presented here. They are the method of grease *extraction* and the method of grease *determination* (by NIR technology).
Alcohol extractable matter (AEM) method
Balance -one for determining the mass of the test specimen to 0.01g; one for determining the mass of the ethyl alcohol extractable matter to 0.001g
Soxhlet extractor – of capacity 250ml, assembled with ground-glass joints to a 250ml distillation flask and suitable reflux condenser
Heating apparatus – having adjustable heat control, for heating the soxhlet flasks
Soxhlet filter thimble – capable of retaining all fine solids, having sufficient length to extend above the top of the siphon, and of sufficient capacity to hold about 10g of wool
Ventilated drying oven – capable of maintaining a temperature of 105±5°C
Suitable stopper – to fit the distillation flask
Near infrared (NIR) method
The NIR is a spectrophotometer which uses near infrared energy to measure the amount of grease remaining in a sample of scoured wool. The NIR method is a non-destructive technique which is applied to the whole of the scoured subsample. To determine the concentration of grease in the scoured sample, the subsample is exposed to near infrared radiation. The reflection of infrared energy is dependent on the molecular and physical properties of the sample at defined

wavelengths. The instrument is calibrated to a range of samples with different grease values. When an unknown sample is presented to the NIR, it rapidly predicts the grease value of that sample.

8.5 Procedures

Presale testing for Yield and Mean Fibre Diameter has been an integral part of the Australian wool selling system since the introduction of Sale by Sample in July, 1972. Today, virtually all Australian wool is tested for Yield and Diameter, irrespective of the method of marketing, and is sold to the processor on test results. In fact, failure to provide presale test information results in reduced competition and in severe price penalties.

The following procedure is employed in determining the Yield from a core test:

Core

A core sample of approximately 1000g is taken from each sale lot. All bales in the lot are sampled, and the bale weights recorded at the time of sampling. A Sampling Officer from the test house oversees the process to ensure that the sampling is conducted in accordance with IWTO standards and to ensure that the samples are secured for dispatch to the laboratory

Batch

Once samples are received in the laboratory, the Testing Officer places samples with similar testing requirements into a ‘batch’. The batches are then processed as a group

Subsample (greasy wool)

(As mentioned in Section 8.4 ‘*Equipment*’, IWTO-19 states that *‘A number of methods are applicable for preparation of the sample and selection of subsamples*.’ For the purposes of this topic however, the procedures used for blending and subsampling within AWTA Ltd are documented.)

The core samples are tipped into a bucket where they are weighed, blended by air and weighed again. The difference between the pre blend and post blend weights is used to calculate a correction factor to compensate for any weight change as a result of the blending process.

Testing Officers then remove 2 or 3 subsamples that weigh 150g each. Classed grower lots require only 2 subsamples. However, bulk class, interlots and lots containing 40 bales or more have 3 subsamples taken because of their greater variability.

The subsamples are put into containers, together with their accompanying paperwork and sent onto scouring. Once subsamples are drawn they are treated individually.

After removing the 150g subsamples from the bulk coresample, the remainder is packaged into an air tight container and stored along with other samples. Known as ‘keeper samples’, they allow further testing, if required, on the lot without the need to recore the bales.

Scour

Subsamples are placed in a washing machine that operates along the same principles as a commercial scour. Subsamples are washed in hot water and detergent before being rinsed twice in cold water.
Scouring removes all the suint and most of the mineral content (sand and dirt) and wool grease. A fine mesh at the base of the scour retains all the wool and all the vegetable matter (VM). Any wool fibre passing through the scour mesh is trapped in the 200 mesh sieve and added back to the scoured sample.

After washing, all the wool fibre and VM are removed from the scour and placed in a drying can. The cans are loaded into a centrifuge, which operates like the spin cycle on a washing machine, and spun to remove excess water.

Note: Provided that certain requirements are met, IWTO-19 allows for the mean mass of floating matter for a large number of individual subsamples to be applied as a factor in the calculation, instead of conducting separate flotations. This is referred to as ‘flotation factor’.

Dry
The drying cans are loaded into ovens that force hot air through the sample at 105°C. Electronic dryer monitors indicate when all the moisture has been removed from the wool. Each subsample is then removed from the oven, weighed and the oven dried scoured weight recorded. By this stage the weight of the subsample is approximately 70 - 90g with about 60 - 80g having been removed from the wool as dirt, suint, grease and moisture.

It is critical that subsampling (see below) from these samples is made from moisture-free samples of wool, so that an accurate determination of all contaminants may be made. As such, IWTO-19 documents a procedure for ensuring that samples of wool are dry. This involves a system of check weighing, whereby samples are weighed, dried and reweighed at 5 minute intervals. This process continues until the change in mass of the oven dry weight of the sample is less than 0.05% of the previous weight. It is permissible, however, to monitor the change in weight by the electronic dryer monitor means described above, provided that the requirements stipulated in IWTO-19 are satisfied.

Subsample (scoured wool)
After scouring and drying, 3 contaminants remain in the wool. These include all the VM that was in the subsample, and a small amount of residual grease and residual dirt not removed during the scouring process. In order to determine Wool Base (WB), these 3 contaminants need to be quantified. At residual subsampling, specimens are taken from the dry scoured subsample and sent to the appropriate area for determination of the residual contamination.

Residual mineral matter analysis
Residual dirt content is determined by burning the dry scoured wool specimen to ash in a furnace. A 10g specimen is removed from the dry scoured subsample. The specimen is packed into a crucible and then combusted in a furnace at a temperature of 750°±50°C. The crucibles take about 2-3 hours to pass through the furnace, during which time wool, vegetable matter and wax in the specimen reduce to almost weightless ash, leaving only the mineral matter in the ash. The residual dirt consists of relatively inert mineral salts which are not affected by the high furnace temperatures. The amount of residual dirt can be weighed and its percentage of the sample weight can be calculated.

Residual grease analysis
Residual grease determination is conducted using the process of Near Infrared Reflectance Analysis (NIR). The scoured and dried log of wool is placed inside a sample tray, which the operator slides underneath the light source. At the completion of the test (about 5 seconds) the predicted grease value for that sample is displayed and the measurement screen will either be red of green, indicating either an unacceptable or acceptable measurement.

For a small percentage of commercial tests however (samples containing black fibres or samples containing >2% grease), the residual grease content is determined using the traditional method of alcohol extraction. Here, hot ethyl alcohol is passed through the dry scoured wool specimen. The alcohol dissolves the wax and any residual detergent left in the sample, and the alcohol is evaporated leaving the grease residue. The residue is weighed and its percentage of the sample weight can be calculated.

Vegetable matter (VM) content analysis
40g specimens of wool are placed into each bowl of a dissolver. 600ml of a 10% solution of boiling sodium hydroxide (caustic soda) is admitted into each bowl and agitated for 3 minutes. After this time, the wool has completely dissolved, but the VM is relatively unaffected. A litre of cold water is added to cease the dissolving action and the solution is poured through a sieve to retain the VM. This can be done manually or by an automated machine.

A water spray nozzle rinses the residue caustic from the TAI. During the rinsing process a tray sits under the sieves to cause the rinse water to bathe the TAI.

After rinsing, any TAI on the side of the funnel is hosed into the sieve and compressed air is used to remove excess moisture from the TAI in each sieve. The sieves containing TAI are then placed into the VM driers, and a fine covering sieve placed on top of the sieves to prevent loss of TAI. The VM is dried in the forced air drier at 110°±2°C.

The sieves containing dry TAI are then placed in sealed containers to cool, awaiting TAI dissection.

The sodium hydroxide affects the VM. The finer and softer particles of VM are more affected by the caustic than the harder ones. In order to correct for this, the VM, after drying, is separated into 3 categories, namely:

- Burrs
- Seed and shive (which loses most weight during dissolving), and
- Hard heads and twigs (which are less affected by caustic soda).

Correction factors for each category have been pre-determined and are applied to the weights of the 3 categories identified so as to gain an estimate of the percentage of each VM category present. The total weight is used to calculate the Vegetable Matter Base (VMB).

In addition to the above VM categories, Testing Officers also identify and separate dag, sand, other alkali insolubles for e.g. dermatitis, and pack material contamination. If Testing Officers find traces of contamination in the VM specimen (e.g. baling twine, pieces of cloth etc), action is taken with the broker that may see the offending bales unpacked in an attempt to find the source of the contamination.

Calculate
Once all of the impurities are known, then the Yield for a subsample can be calculated. This is achieved by deducting the analysed percentage of each residual impurity from the weight of the oven dry log to determine the clean, dry fibre content for each subsample. The clean, dry fibre content is expressed as a percentage of the greasy sample, and this value is referred to as the (%) Wool Base. The (%) Wool Base is then converted to a (%) Yield by applying the appropriate conversion factor and processing allowance for the particular Yield to be estimated.

The different types of Yield estimates are presented in section 5.7 '*Derived Yield Estimates'*.

8.6 Standards

To gain recognition and acceptance, a testing laboratory must agree to issue certificates of Yield according to international standards. International standards are necessary so that all laboratories will conduct their tests by similar methods. This way, a client could feasibly test his clip in any laboratory operating to international standards, anywhere in the world, with the assurance that an equivalent result would be obtained.

The first accepted standard of testing was the American Society for Testing Material Standard D584 (ASTM). This was established in 1940 and used by the U.S. Customs department to core test all imported wool to determine the clean wool percentage. The ASTM standard, still in use in the U.S.A., has been the basis for the development of the International Wool Testing Organisation Standard (IWTO) and the Yield standard of the Standards Association of Australia.

Establishing a standard

It is important to appreciate how a testing standard is established. Generally, the need for a standard is suggested by the industry. If the need is genuine, the Standards organisation of the industry establishes a committee to examine the problems and requirements necessary to develop a standard. The committee usually involves commercial and technical personnel with the assistance of technical working groups. Once a standard is drawn up in draft form, it is passed through other industry committees for comment, criticism and amendment. Finally, the draft is completed and issued as an official standard on which contracts can be referred to, and which testing houses will follow.

Once a standard is established it is regularly reviewed. New techniques, practical problems, or difficulties in interpretation might make it necessary for regular amendments to be made to the standard.

For Yield, the focus is on the IWTO standard "*Determination of Wool Base and Vegetable Matter Base of Core Samples of Raw Wool*" (IWTO-19-03), the IWTO Core test Regulations and the Australian Standard “Determination of washing Yield and clean fleece weight” (AS/NZS 4492.2:2000).

IWTO-19-03

This method has been prepared by the members of the IWTO Raw Wool Certification Sub-committee, Technical Section. It is based on the experience of laboratories which have carried out a series of co-operative trials over several years.

The Standard is applicable to core samples only and covers all forms of raw wool. It sets out the procedures to be used for determination of the Wool Base and Vegetable Matter Base, from which the commercial Yields of classed growers’ lots, interlots, bulk classed lots and deliveries are calculated.

IWTO core test regulations

These regulations relate to the core sampling and testing of raw wool, the calculation of commercial Yields and the issuing of IWTO Test Certificates and IWTO Combined Certificates.

AS/NZS 4492.2:2000

This Standard sets out procedures for determining the washing Yield of a sample taken from a greasy fleece, and the clean fleece weight of the fleece from which that sample was drawn. Its objective is to provide the wool industry with a method of determining the washing Yield and clean fleece weight of wool for the purpose of ranking sheep.

When this Standard is used for making direct comparisons between sheep, the sheep shall be from the same drop (age group); they shall have been run together under the same conditions for the period of wool growth to which the measurements refer; and all wool samples shall have been taken from the same site on each sheep.

The procedures for this application are described more fully in section 8.8 *‘Yield Testing of Fleeces’*.

8.7 Derived yield estimates

Yields may be expressed either as nett clean mass of a lot or delivery, or as the nett clean mass expressed as a percentage of the nett greasy mass. The different types of Yield estimates are given below:

Theoretical top and noil yield

Theoretical Top and Noil Yield is defined as the maximum Yield which theoretically could be obtained if all the wool fibre in a lot could be converted to top and noil without processing loss.

The Theoretical Top and Noil Yield is calculated from Wool Base using appropriate conversion factors as follows:

- Schlumberger Combed Dry (1.0% TFM) = Wool Base x 1.207
- Schlumberger Combed in Oil (4.6% TFM) = Wool Base x 1.257
- Noble Combed Dry (1.0% TFM) = Wool Base x 1.205
- Noble Combed in Oil (4.6% TFM) = Wool Base x 1.255

The above calculations are based on the general equation for Theoretical Top and Noil Yield (TTNY) namely:

$$TTNY = B \times \left(\frac{99.01}{97.73}\right) \times \left(\frac{100+R}{100}\right) \times \left(\frac{100+F}{100}\right) \times \left(\frac{t+1}{\left(\frac{t+100+R}{100+R}\right) \times \left(\frac{100+F}{10+f}\right)}\right)$$ where

B	=	Wool Base %
R	=	Regain % of Top
F	=	Total Fatty Matter Content (TFM %) of Top
r	=	Regain % of Noil
f	=	TFM % of Noil
t	=	Tear Ratio (conditioned weight of Top divided by conditioned weight of Noil)

For the standard IWTO Theoretical Top and Noil Yields given above it is assumed that the TFM % contents of Top and Noil are equal and that a tear ratio of 8:1 is achieved.

Estimated commercial top and noil yield

Estimated Commercial Top and Noil Yield (ECTNY) is defined as the Theoretical Top and Noil Yield (TTNY) less an allowance, PA (Processing Allowance) for fibre loss in processing of the wool to the top stage.

The conversion from Theoretical Top and Noil Yield to Estimated Commercial Top and Noil Yield is to be made in accordance with the following formula:

$$ECTNY = TTNY - PA$$

Where:

For Schlumberger Combed Wools $PA = 2.5 + VA$;

For Noble Combed Wools $PA = 2.0 + VA$

VA is the allowance for wool removed with vegetable matter during processing based on VM and calculated according to the following regression equation:

$$VA = 5.20 - \frac{4.60}{7.80 + VM}$$

where VM is the Vegetable Matter Base, excluding Hard Heads and Twigs Base.

IWTO Schlumberger dry top and noil yield

The IWTO Schlumberger Dry Top and Noil Yield is the most commonly used commercial Core Test Yield, and predicts the amount of Top and Noil that can be combed from the greasy wool. It is the main Yield basis for wools traded in Western Europe.

An allowance of 2.27% is made for residual ash and alcohol extractives. 18.25% Regain is added to the Top and 16% Regain is added to the Noil. The total fatty matter content (TFM) is 1% and a tear ratio (the ratio of conditioned weight of Top to the conditioned weight of Noil) of 8:1 is assumed. The conversion factor of 1.207 applied to Wool Base takes account of these factors.

The Schlumberger combing Yields include a processing allowance for fibres lost during processing. This processing allowance will vary according to the Vegetable Matter Base (VMB) and Hard Head (HH) content and is calculated according to the following formula:

$$PA = 7.7 - \frac{40.6}{(7.8 + VMB - HH)}$$

The calculation basis for the Schlumberger Dry Top and Noil Yield is:

$$Schlum\ Dry = (B \times 1.207) - PA$$

Theoretical card sliver yield

Theoretical Card Sliver Yield is defined as the maximum Yield of card sliver which could theoretically be obtained if all the wool fibre in a lot could be converted into card sliver without processing loss. This is derived from Wool Base adjusted to a standard ash plus ethyl alcohol extractives content of 2.27% and brought finally to a regain of 18.25%. That is:

$$Theoretical\ Card\ Sliver\ Yield = B \times \frac{118.25}{97.73} = B \times 1.210$$

Estimated commercial card sliver yield

Estimated Commercial Card Sliver Yield (ECCSY) is defined as the Theoretical Card Sliver Yield (TCST) less an appropriate allowance for fibre loss in processing the wool to the card sliver stage.

The conversion from Theoretical Card Sliver Yield to Estimated Commercial Card Sliver Yield is to be made in accordance with the following formula:

$$ECCSY = TCSY - (2 + VA))$$

where VA is an allowance for wool removed with vegetable matter during processing (defined earlier for *Estimated Commercial Top and Noil Yield*).

IWTO scoured yield, 17% regain

The IWTO Scoured Yield at 17% regain, SCD (17%), is calculated from Wool Base and Vegetable Matter Base. An allowance of 2.27% is made for residual ash and alcohol extractives and 17% Regain is included. This Yield estimates the 'washing Yield', i.e. the Yield of product obtained after scouring but before any processing occurs to remove Vegetable Matter. It is commonly used in trade with Eastern Europe and the USSR.

The calculation basis for this Yield is:

$$SCD(17\%) = \frac{(B - VMB) \times 117}{(100 - 2.27)} = (B - VMB) \times 1.1972$$

Japanese Clean Scoured Yield (JCSY)

Japanese Clean Scoured Yield is the normal basis for trade with Japan. An allowance of 1.5% is made for residual ash and alcohol extractives, and 16% Regain is included. Although this Yield has the Vegetable Matter deducted, no allowance is made for fibre loss which would occur during processing.

The calculation basis for this Yield is:

$$JCSY = \frac{B \times 116}{(100 - 1.5)} = B \times 1.1777$$

Australian Carbonising Yield, 17% Regain (ACY)

Australian Carbonising Yield is popular in Australia, Japan, Korea and Belgium as the basis of trade in carbonising and carding types (lox, crutchings, lambs, etc). An allowance is made 2.27% is made for residual ash and alcohol extractives and 17% Regain is included. The Yield calculation from Wool Base and Vegetable Matter Base allows for expected processing losses during carbonising.

The calculation basis for this Yield is:

$$ACY = B \times 1.1972 + VMB \times 0.162 - 5.12$$

ASTM Clean Wool Fibre Present

The calculation basis for this Yield is:

$$ASTM\ Clean\ Wool\ Fibre\ Content = \frac{B \times 113.64}{97.73} = B \times 1.1628$$

Washing Yield

Washing Yield is used to determine the Yield from samples of individual fleeces (This is described more fully in Section 5.8 *Yield Testing of Fleeces*).
The calculation basis for this Yield is:

$$Washing\ Yield = \frac{ODW \times 116}{100} = ODW \times 1.16$$

where ODW = the Oven Dried Weight after scouring, expressed as a percentage.

The Washing Yield is normally expressed at 16% regain.

8.8 Yield testing of fleeces

Determination of fleece Yield is important to the wool grower for

- selection of the best rams and ewes for breeding purposes, and
- wool classing purposes.

Yield is measured by scouring a sample of fleece wool. An estimate of a sheep's clean fleece weight is then obtained by multiplying its greasy fleece weight by its percentage Yield.

Of the two measurements of wool production, greasy fleece weight is of more current value to the breeder than clean fleece weight, as greasy wool is the form in which the clip is sold. The simplest estimate of fleece value comes from the weight of greasy wool produced by a sheep, multiplied by the price per kilogram paid for the line into which the fleece was graded for sale.

Yield is measured on a sample of wool taken from the left mid-side of the fleece. The mid-side is chosen because this has a Yield that is closest to the average for the whole fleece, excluding the belly. The left side is specified as this is closer shorn with less second cuts. Other standard sites such as the mid-shoulder may be sampled in order to rank rams on clean fleece weight. However, shoulder Yields are above the average of the whole fleece.

Midside samples are taken to a Test House and tested for Yield by undertaking the following steps:

Sample receival:
The sample is received by the testing house, where it is allocated some form of identification, cross referenced to the growers own identification.

Subsample:

1. The subsample must be representative of the sample from which it was taken
2. For the determination of washing Yield and the measurement of mean fibre diameter only, a mass of not less than 30g must be used. When residual grease and residual ash are determined in conjunction with an airflow determination for fibre diameter, a subsample mass of not less than 50g must be used
3. Weigh and record the subsample to 0.1g.

Scour:

1. Scouring must be by an aqueous method where the sample is washed in hot water and rinsed. It is best practice to stir the sample during scouring and to avoid agitation, as this would introduce roping to the wool

2. If the monitoring of fibre loss from wool subsamples, either scoured one at a time or scoured as a group, is required (these procedures are set out in Appendix A and Appendix B of AS/NZS 4492.2:2000, and are not included in these topic notes) the mass of the sieve contents, as a percentage of the combined mass of the greasy subsamples must not exceed 0.3% of the mass of the subset of subsamples before scouring
3. Where applicable, the number of subsamples with more than 2% grease shall not be more than 5% of the number of subsamples in the analysis group
4. Where applicable, the number of subsamples with more than 2.5% ash shall not be more than 5% of the number of subsamples in the analysis group. (Residual levels of less than 2% for grease, and less than 2.5% for ash are achievable for most wools, but very greasy or dusty samples may require a more rigorous scouring program to achieve this result).

Centrifuge:
Centrifuge the samples to remove excess water.

Dry:
1. Wool or vegetable matter shall not be lost from the subsamples on transferral or during drying or weighing
2. Drying cans or other containers used to hold the subsamples shall be clean and free of contamination from previous subsamples
3. Drying shall be carried out using air at a temperature of 105±2°C
4. If a forced air drier and drying cans are used –
    a) the size and shape of the drying can shall be such as to minimise uneven flow of air through the subsample
    b) the drying can shall be fitted with mesh ends, with apertures not larger than 150μm, to prevent loss of either wool fibre or vegetable matter during drying
    c) the mesh ends of the drying can shall be strong enough to retain the subsample under the full force of the drying air
    d) the subsample shall be packed evenly into the drying can so as to achieve a uniform packing density, and
    e) drying positions not in use shall be blocked off.
5. The balance shall be shielded to shut out draughts
6. Weighing out shall be undertaken using a balance with a readability of 0.1g or better
7. The subsample shall be considered dry when the mass loss, at the end of the estimated drying time, is less than 0.1% per minute of the previously recorded mass of the subsample over an interval equal to at least 30% of the estimated drying time, but not less than 5 minutes
8. Record the mass of the oven dry, scoured subsample to 0.1g.

Calculation:
The washing Yield shall be calculated using the following equation:

$$Washing\ Yield = \frac{Mass\ of\ Oven\ Dry\ Scoured\ Subsample}{Mass\ of\ the\ Greasy\ Subsample} \times 116$$

It should be noted that, for high Yielding wools, it is possible to achieve a washing Yield in excess of 100%.

Readings [3]

The following reading is available on CD:

1. Australian Wool Testing Authority (AWTA), 2002, Testing the WoolClip, AWTA Ltd.

Activities

Available on WebCT

Multi-Choice Questions

Submit answers via WebCT

Useful Web Links

Available on WebCT

Assignment Questions

Choose ONE question from ONE of the topics as your assignment. Short answer questions appear on WebCT. Submit your answer via WebCT

Summary

Summary Slides are available on CD

This topic has focused on the estimation of Yield according to standard test methods and the Standards applicable to the estimation of Yield. The reader will, by now, be aware that wools are processed in many different ways by different machines and techniques. Therefore the actual commercial Yield of fibre will depend on the type of processing. Consequently, to maximise the use of core testing for Yield in trading, it has been shown that the Wool Base Yield must be converted into a consistent realistic Commercial Yield.

The importance of Yield measurement

- to parties buying and selling wool
- to Top makers, and
- to textile manufacturers

has also been defined.

The systems for determining Yield (and other key parameters) are well established and in everyday use in mill specifications, performance monitoring and commercial transactions.

Movies

The following movies are available on CD:

- Australian Wool Testing Authority Ltd. (AWTA), Coresampling.
- Australian Wool Testing Authority Ltd. (AWTA), Blending.
- Australian Wool Testing Authority Ltd. (AWTA), Scouring and Drying.
- Australian Wool Testing Authority Ltd. (AWTA), Ashing.
- Australian Wool Testing Authority Ltd. (AWTA), Dissolving.

Australian Wool Testing Authority Ltd. (AWTA), Grease.

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American Society for Testing and Materials (ASTM) Standard Service - Textiles. ASTM International, West Conshohocken, P.A., U.S.A.

AS/NZS 4492:2000, Wool – Fleece Testing and Measurement, Method 2: Determination of washing Yield and clean fleece weight.

ASTM D584-96, 2005, Standard Test Method for Wool Content of Raw Wool – Laboratory Scale.

Australian Wool Corporation (AWC), 1989, Understanding Australian Test Certificates for Greasy Wool, AWC, Raw Wool Services.

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Australian Wool Testing Authority Ltd. (AWTA) website, Wool Testing Correspondence Course, Units 8 and 13.

Australian Wool Testing Authority Ltd. (AWTA), Yield and Micron Manual.

Australian Wool Testing Authority Ltd. (AWTA), 1990, Wool Testing Handbook, September 1990.

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Harmsworth, T. and Day, G. 1979, *Wool and Mohair,* Inkata Press Pty Ltd, Melbourne.

IWTO-19-03, Determination of Wool Base and Vegetable Matter Base of Core Samples of Raw Wool, International Wool Textile Organisation test method.

IWTO-31-02, Calculation of IWTO Combined Certificates for Deliveries of Raw Wool, International Wool Textile Organisation test method.

IWTO, 2004, Core Test Regulations, May 2004.

Glossary of terms

Carbonise	to treat wool with sulphuric acid, followed by baking, which embrittles burrs present so that they can be easily broken up, crushed and removed
Greasy wool	wool from the sheep's back or sheepskins which has not been scoured, solvent degreased or carbonised or otherwise processed. It contains grease and suint extruded from the follicles in the skin and dirt and Vegetable Matter picked up from grazing Hard Heads and Twigs Base (HH%) - the oven-dry mass of ash-free, ethyl alcohol extractives-free hard heads and twigs, expressed as a percentage of the mass of the sample
IWTO Combined Certificate	a certificate resulting from the mathematical combination of IWTO Test Certificates, calculated in accordance with the appropriate IWTO Test Method
IWTO Combined Certificate (by Subtraction)	a certificate resulting from the mathematical subtraction of a separately tested and certified component from a consignment which is covered by an IWTO Test Certificate or an IWTO Combined Test Certificate, calculated in accordance with the appropriate IWTO Test Method
IWTO Test Certificate	a certificate resulting from the testing of samples drawn in accordance with the relevant IWTO Test Regulations, and in accordance with the appropriate IWTO Test Method. keeper samples - see test house samples
Noil	the short fibres removed during the combing process; it comprises second cuts, pieces of broken fibres, neps, and is contaminated by small pieces of vegetable matter
Tear	the mass ratio of top to noil produced by combing
Top	sliver that forms part of the starting material for the worsted and certain other drawing systems, usually obtained by the process of combing, and characterised by the following properties: (a) A substantially parallel formation of the fibres, essentially free of vegetable matter (b) The absence of fibres so short as to be uncontrolled in the preferred system of drawing (c) A substantially homogeneous distribution throughout the sliver of fibres from each length group present
Vegetable Matter Base (VMB%)	the oven-dry mass of ash-free, ethanol-extractives-free burrs (including hard heads), twigs, seeds, leaves and grasses present, expressed as a percentage of the mass of the sample
Yield	the amount of clean fibre, at a standard regain, that is expected to be produced when a delivery of raw wool is processed. The yield may be expressed both as a clean mass in kilograms and as a percentage of the mass of raw wool prior to processing