12. Contamination

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Learning objectives

- By the end of this topic you should have an understanding of:
- The source of contamination:
    - contamination of wool origin; viz. urine-stained, pigmented and medullated fibres
    - contamination of non-wool origin, viz. wool packs, farm objects (including baling twine), mill packs and mill objects
- The problems created by each form of contamination
- Methods to minimise the risk of contamination
- Future developments

Key terms and concepts

Urine-stained fibre, pigmented fibre, medullated fibre, dark and coloured fibres, exotic sheep, AWEX Code of Practice, Dark and Medullated Fibre Risk (DMFR) Scheme, Dark and Medullated Fibre (DMF) Test, testing standards, within-pack contamination, wool pack contamination.

Introduction to the topic

This topic describes the main forms for "contamination" occurring in the Australian wool clip. Contamination, which is considered a major issue by early and late stage processors, includes man-made fibres, dark and medullated fibres, skin pieces through to chemical residues.

Generally contamination can be classified as being of wool or non-wool origin. Wool origin contamination takes the form of urine-stained, pigmented and medullated fibres. Contamination of non-wool origin includes vegetable matter and other animal fibres (e.g. dog or horse hair, alpaca fibre), as well as man-made products such as wool packs, baling twine, fertiliser bags, other yarns and fabrics, etc.

This topic will consider the following forms of contamination:
- contamination of wool origin; viz. urine-stained, pigmented and medullated fibres
- contamination of non-wool-origin, viz. wool packs, farm objects (including baling twine), mill packs and mill objects.

We will not consider branding fluids, skin pieces, vegetable matter or chemical residues.

12.1 Contamination of wool origin

This section outlines origin of dark and medullated fibres (DMF) in wool from both Merino and non-Merino sheep.

The problem of DMF contamination

Dark fibres

Dark fibres cause problems for the processor because a single dark fibre in a white or pastel fabric will appear as a fault (Foulds, Wong and Andrews 1984). A single fibre lying on the surface of a yarn manifests as a thin dark line on the fabric (see Figure 12.1). If the dark fibre lies within the yarn structure is appears as a smudge.

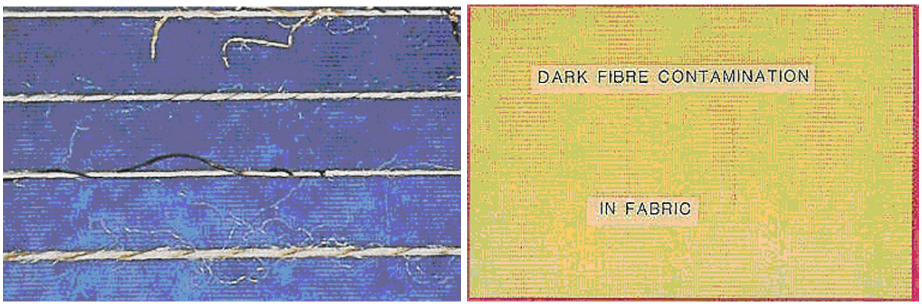


Figure 12.1 Dark fibre contamination in a yarn and fabric. Source: CSIRO (1992).

All fabric structures can be affected but in worsted yarns and fabrics, the dark lines are more noticeable; whereas a smudge is more evident in wool processed on the woollen system. Depending on the number of dark fibres, picking (or manual removal) is required (see Figure 12.2). If the contamination levels are too high such that the fabric would be damaged through picking or it would cost too much, then the fabric may be dyed to a darker shade. As with picking, corrective dyeing is performed at additional cost. Compensation for financial loss is claimed on the spinner, who subsequently makes a claim on the topmaker. Costs range from a share of the picking costs to the total replacement of the fabric.

Dark fibres may be detected at the top stage, allowing some possibility that the contamination is identified and the wool re-directed to a more appropriate end-use. However, like other textile industries, the wool industry is focused on providing a "just-in-time" response to the consumer. So while there may be a use for the contaminated wool, it is still necessary to find an immediate replacement for that top, which again may prove costly for the spinner.

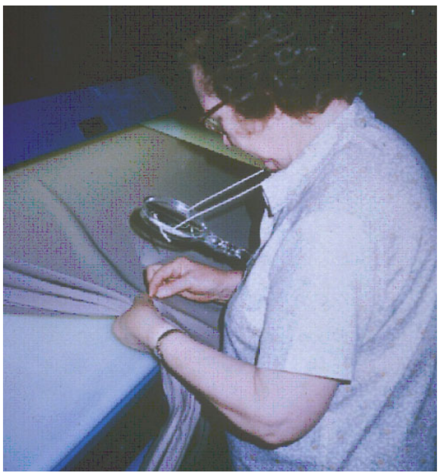


Figure 12.2 Picking fabric in commercial mill. Source: CSIRO (1992) with permission.

Medullated fibres

Medullated fibres create problems because they do not take up dyes in the same manner as normal fibres. Contamination by medullated fibres creates the converse problem to that of dark fibres (Tester 2002). That is, in dark coloured fabrics, medullated fibres give a different, often white, appearance. The problem is exacerbated as the depth of colour of the fabric increases.

If the contamination is detected in the top stage, the batch may be dyed a lighter shade or mixture of colours. It is much more difficult to remedy medullated fibre contamination by dyeing at the fabric stage. Picking may be employed to rectify the problem; providing it is cost effective.

Extent of and penalties for contamination

Discounts are applied to greasy wool contaminated with dark or medullated fibres; however, without a routine test the penalties are not clear. Discounts of 15 to 35% have been calculated for dark fibre, and this is in agreement with penalties applied to wools carrying a "Y" suffix for black and grey wool in its AWEX ID (Fleet, Mahar and Turk 2002). The penalty increases as the scaled qualifier increases from Y1 to Y3. Similar penalties have been reported for medullation; however, less information is available due to the low usage of the scaled qualifier "P", for kemp.

Commercial limits of less than 100 dark fibres per kilogram (<100 df/kg) is the rule of thumb for dark fibre contamination in tops intended for white and/or pastel end-uses (Foulds, Wong and Andrews 1984). Even lower limits may apply to ultra-high end use products such as undergarments (<50 df/kg). Three dark fibres per running metre of fabric are thought to result from 100 df/kg top. For medullation, limits are not usually specified, though it might be extrapolated that they would be the same as for dark fibre, that is <100 medullated fibres per kilogram (<100 mf/kg) top.

As mentioned previously, compensation for losses incurred through the delivery of a consignment contaminated with dark fibres range from a shares of the costs of, for example, picking through to total replacement of the fabric. These costs are passed from weaver to spinner to topmaker.

Origin of contamination

Dark fibres

There are two categories of dark fibres: urine-stained, where continued exposure to urine results in a permanent stain, and pigmented where the protein melanin produced in melanocytes in the follicle moves into skin, wool or hair (Foulds, Wong and Andrews 1984) (see Figure 12.3). In terms of causing contamination, urine-stain poses a bigger problem than pigmentation for Merino wool. Note: water stain, ectoparasite infestation, dag or yolk do not cause dark fibre contamination as the colours are not dark enough.

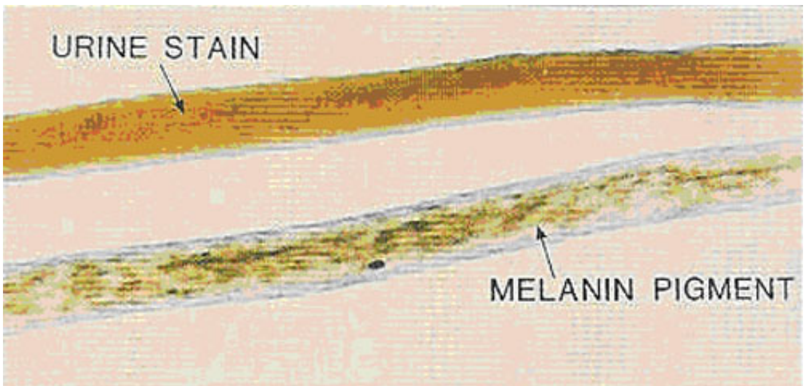


Figure 12.3 Sources of dark fibre contamination: urine stain and pigmentation.
Source: CSIRO (1992) with permission.

Urine-stained fibres

Urine-stained fibres vary in colour from pale yellow to black, largely in response to the length of exposure of the wool to urine. While the fibres are uniformly discolored, the tips may be darker due to longer exposure (see Figure 12.3). Generally, only brown fibres with a CSIRO Colour Reference greater than 4 are dark enough to cause problems in knitted or woven fabric (Foulds, Wong and Andrews 1982) (see Section 12.3).

A number of factors contribute to the occurrence of urine stain (Foulds 1983; Foulds 1985; Foulds 1988). The primary factor determining the occurrence of urine-stain is the sex of the sheep. For wethers, the urine-stain is found in the belly wool around the pizzle, with this region removed first during shearing. Thus, the likelihood of contamination is reduced compared to ewes. For ewes, the crutch stain is removed at the end of shearing, thus greatly increasing the possibility of contamination.

The crutch/shear interval (time between crutching and shearing) is another major determinant of the risk of urine-stain. If the crutch/shear interval is less than 3 months, and wool from the pizzle of wethers and crutch in ewes, remains with the fleece wool, contamination is highly unlikely. This is because the stain is yellow or pale brown, which does not translate to a problem in the fabric. In addition, as the stained fibres are short (<3 month growth), they fall out during topmaking.

Other factors that may make a minor contribution to the risk of contamination from urine-stain include: mulesing, pizzle dropping, tail docking, the amount of wool on the hind legs, fleece cohesion, pasture type and rainfall.

Pigmented fibres

Melanocytes, which are found along the epidermal/dermal border, outer root sheath and hair follicle bulbs, produce the protein melanin (Fleet 1985). Melanin granules transfer into cells called keratinocytes, which then develop into wool, hair or dead layers of skin. As shown in Figure 12.3, pigmentation in wool may not be uniform due to the granular nature of melanin.

Considerable research has been undertaken to understand pigmentation of Merino wool (Fleet 1985; Fleet and Foulds 1988). Pigmentation is usually genetic in origin and is the result of a recessive gene. Minor environmental influences can occur, for example, copper is required for the formation of melanin. The following summarizes the five common types of pigmentation in Merino sheep and aspects related to flock management:

- Piebald sheep have one or more patches of pigmentation (and/or kemp). Black and piebald lambs need to be culled, and if possible their parents as these are the carriers of the recessive gene
- Coloured birth coats appear as tan patches, usually on the neck. Although these tan patches are generally shed soon after birth, culling is recommended for those with extensive patches. Lambs showing dark halo hair and/or pigmentation on their legs or horn sites should also be culled due to their predisposition for isolated pigmentation later in life
- Isolated pigmented fibres are hard to detect and are hard to control. If pigmented spots or fibres are identified, the sheep should be culled
- Non-wool pigmentation is that found on hooves, horns, legs, inside the mouth, eyelashes, nose and lips. This form of pigmentation generally increases with age. Pigmented leg hair is a strong indicator of isolated pigmentation. However, as most forms of non-wool pigmentation is correlated with isolated pigmentation, it is recommended that such sheep be culled
- Non-congenital pigmentation, otherwise known as age spots, develop over time, although the sheep has to be quite old before that spots are considered significant. They are often found along the back line where they develop in response to exposure to the sun.

Medullated Fibres

Coarse fibres that posses a medulla (core of air-filled cells) are hairy and harsh in handle (Balasingam 2005). The medulla may be continuous, interrupted, or fragmented (see Figure 12.4. In severe cases, most of the interior of the fibre is affected, and the fibre tends to become flattened, chalky-white and brittle - such fibres are generally known as "kemp". Note, for wool the term kemp is often used for shorter fibres that have been shed into the fleece.

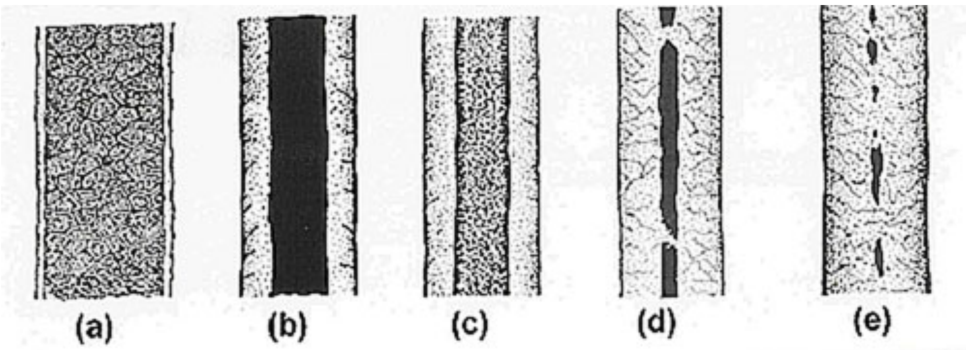


Figure 12.4 Fibre medullation: (a) unbroken lattice, (b) simple unbroken (c) simple unbroken (in-filled with mounting medium) (d) interrupted and (e) fragmented.
Source: Wildman (1954) cited by Balasingam (2005).

Difference in DMF content of sheep breeds

Merino

In terms of evolution, the Merino is considered the most highly developed breed as it grows wool continuously, it has a high secondary to primary (S:P) ratio and little difference in the size of the follicles such that medullation is rare except in very coarse fibres (Hatcher 2002). Due to careful breeding, the occurrence of pigmentation is also low. Thus medullated and pigmented fibre contamination is not considered a major problem for Australian Merino wool.

Studies have revealed that major source of dark fibre contamination in Australian Merino wool is urine-stain (Foulds, Wong and Andrews 1984). This was confirmed from measurements made of tops produced from various single lines of wool where fleece wool had lowest dark fibre counts followed by pieces and then bellies. In addition, the dark fibre content of each line was proportional to the level of stain in the mob, with where wool with the highest stain levels in the bellies also had high stain levels in the fleece wool.

Non-merino breeds

By comparison, other breeds have to a greater or lesser extent, some of the characteristics of wild sheep such a coarse outer coat and fine undercoat that is moulted in spring as well as different coloured fibre for camouflage purposes (Hatcher 2002). Note: Studies of the urine-stain content of non-Merino breeds have not been undertaken; however, it is likely that the same factors will contribute to potential.

Four fleece types are now recognized; hair, long-wool, double coated and Merino, with the types differentiated on the basis of the size and shape of the follicle, the number and arrangement of follicle groups and the type of fibre grown and the secondary to primary (S:P) follicle ratio. In Australia, the common non-Merino breeds are:

Hair sheep are similar to wild sheep in that they have low S:P ratio producing a short kempy outer coat with fine wool fibres underneath, with colours ranging from white to brown to black. The coarse fibre is highly medullated. The Damara and Dorper are examples of hair sheep. They are commonly crossed with Merinos for meat production.

Double-coated sheep have coats similar to wild sheep with the primary follicles producing long, medullated hairs that eventually shed. The colours range from white, browns, red and black. The Awassi and Karakul were introduced to Australia to meet the requirements of the live sheep trade to the Middle East.

British breeds have a wide variation in their coast ranging from long and lustrous for long wools to short fine Downs wool, with pigmentation and medullation common. Long-wool breeds include: Leister, Lincoln, Border Leister, Romney and Cheviot. Mountain or Highland sheep include the Welsh Mountain and Scottish Blackface; while Short-Wool Breeds include Southdown, Dorset Horn, Suffolk and Wiltshire Horn.

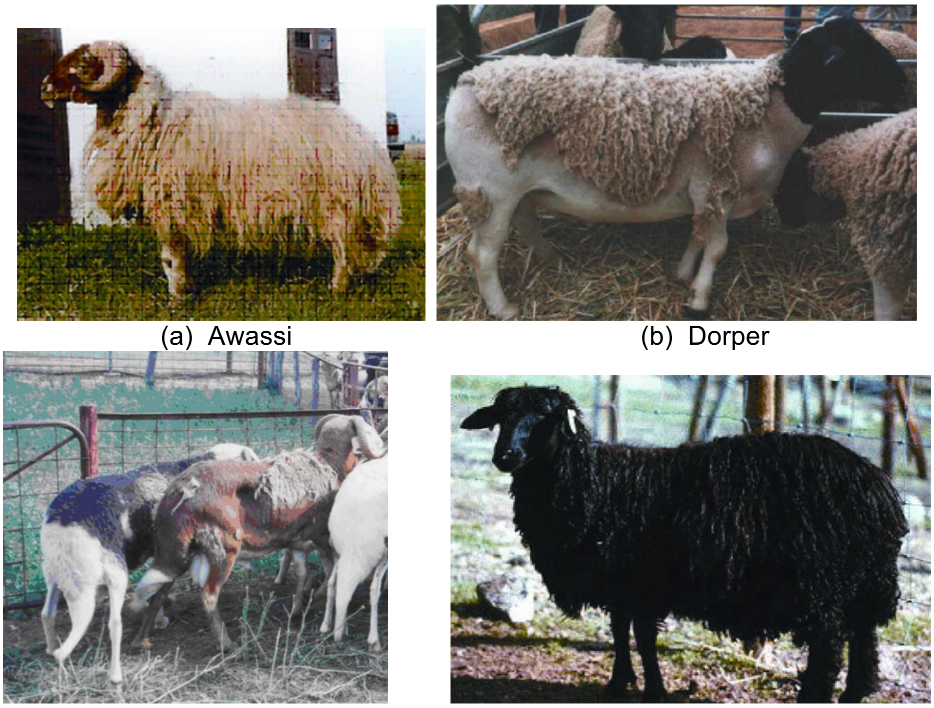
European breeds such as the Finn and Texel, which are primarily used for meat, are not common in Australia. However, their wool is not suited to sensitive end-uses due to potential pigmentation and medullated.

Carpet wool breeds such as the Drysdale and Tukidale are not common in Australia. Their fleece is highly medullated; however, it is mainly sold to the carpet wool industry.

Cross-bred is the terms used to a mix breeds, often the Merino with something else. It is usual that the fleece is a blend of characteristics; therefore, there it has a high risk of dark and/or medullated fibres.

AWEX breed risk rating

The Australian Wool Exchange (AWEX) has developed as part of its Code of Practice (COP) a Breed Risk Rating for contamination, which ranks each breed on the degree of pigmentation, medullation and whether fibres are shed (AWEX 2004). The Merino, including the sub-types Australian Superfine, Dohne, and South African Meat Merino (SAMM), has the lowest rating of 1. On the other hand, the shedding breeds (often called "exotics") of the Awassi, Damara, Dorper and Karakul have the highest Breed Risk Rating of 5. All other breeds found in Australia are ranked somewhere in between. The AWEX Breed Risk Rating has relevance to the Dark and Medullated Fibre Risk Scheme (see Section 12.2).



(a) Awassi (b) Dorper

(c) Damara (d) Karakul

Figure 12.5 Exotic breeds with an AWEX Breed Risk Rating of 5. Source: Douglas (2001) (a) and (b) and Fleet (2000) (c) and (d).

Exotic sheep in Australia

The live sheep trade commenced in Australia in the 1970s with Merino wethers the main supply. However, the immigrant workers of oil-rich Middle Eastern countries did not rate the Merino meat highly. Thus, exotic (fat tailed) sheep were introduced to capture this higher priced market (Douglas 2001; Fleet Mahar and Turk 2002).

In 1986, the Western Australian Department of Agriculture initiated a project to establish the Awassi breed in Western Australia. Using embryo transfer to sheep in quarantine on the Cocos Island and department field stations, the Awassi were brought into Australia via Cyprus. Once established, the flock was expanded by back-crossing over Merino on selected properties.

By the 1990s, low wool prices forced growers to look for other enterprises. With the continuation of the live sheep trade for Middle East Trade, new exotic breeds introduced and aggressively promoted, e.g. Damaras, Dorpers and Karakuls. Further expansion of the exotic sheep population came with the finding that exotics hardier than Merinos. Thus they offered a meat production option to wool growers in semi-arid pastoral areas as well as being attractive to producers in farming country.

Exotics and their crosses now spread across Australia and while exact numbers are not known, there is thought to 1 million out of a total of approx. 100 million sheep. Due to continued favourable meat prices and ongoing concern over future prices for wool, it seems that exotics and their crosses will remain.

12.2 Minimising the risk of wool origin contamination on-farm

Australian Merino woolgrowers have responded to industry feedback related to DMF contamination of their wool. Various methods have been or are being developed to minimise the risk of contamination of "clean", white wool.

Independent "local" action

In some circumstances, wool brokers have taken the initiative to ensure that exotic fibre (e.g. Awassis in WA), is directed to a single selling source, and that it is clearly identified as such for and is stored in a separate part of the wool store. In addition, brokers also offer Merino wool that has been in contact with exotics in a separate tender sale, thus minimising the risk of contamination as well as allowing such wool to be clearly identified at sale.

Tasmania differs from all other Australian States in that it has enacted legislation that treats exotics and their crosses as prescribed animals, thus imposes restrictions on management, transport and advice to neighbours (Thirkell-Johnston 2005, pers. comm.). In this way, the threat of DMF contamination of Merino wool via contact is removed. It is unlikely that this action can be taken by other States.

AWEX code of practice

The AWEX COP (AWEX 2004) is the industry standard for clip preparation that must be used by wool classers and owner classers. One component of the AWEX COP is an industry description of wool called the AWEX ID, which provides a standard set of descriptors applicable to all wool sold in Australia. To help minimise the risk of contamination, the AWEX ID system has descriptors related to dark and medullated fibre, namely: Y (pigment), P (kemp) and S (stain). The COP stipulates that a Y or P suffix be in the description of all wool from sheep in contact with exotics or their crosses. In addition, these wools are to be isolated on the show floor and in the sale catalogue.

To meet the COP, it is also specifies that shearing sheds must be cleaned between shearing "contaminated" wool and shearing Merinos and that there is a dedicated area for pigmented/medullated wool. Finally, an order of shearing, where sheep with the lowest risk of contamination shorn first followed by those of higher risk, i.e. white wool sheep (Merinos), mated to exotics, sucking or running with exotic cross lambs, white culls with obvious pigmented/medullated fibres to breeds showing pigmentation/medullation. Note: Merinos have the lowest AWEX COP breed risk rating of 1 on a scoring system of 1 to 5, while exotics are the highest at 5.

Dark and medullated fibre risk declaration

Background

While the practices described above help to minimise the risk of DMF contamination resulting from contact with exotics, the Australian wool industry felt it constructive to implement a system that would consider both isolated DMF contamination as well as that due to contact with exotics.

The Federation of Australian Wool Organisations (FAWO) with funding from Australia Wool Innovation (AWI) initiated a project aimed at the introduction of a voluntary vendor (woolgrower) declaration for the risk of DMF contamination (Hansford 2003; Hansford and Australian Wool Industry Working Group 2003).

Thus, the Dark and Medullated Fibre Risk (DMFR) Scheme, which has International Wool Textile Organisation (IWTO) endorsement in its Core Test Regulations was introduced in July 2004, with the "Risk Rating" now reported on test certificates and in sale catalogues. The purpose of the Scheme provides white wool producers with the opportunity to identify their product as such; while buyers/processors have objective information on the potential risk of contamination.

Dark fibre risk scheme

The DMFR Scheme was founded on research conducted in the 1980s and 90s, primarily by staff of CSIRO and South Australian Department of Agriculture, who identified the major factors contributing to dark fibre contamination of Merino wool (Foulds 1988). Their work ultimately resulted in a prediction scheme for urine-stained and/or isolated pigmented fibre. This Dark Fibre Risk Scheme, which was validated by processing trials (see Table 12.1), calculated the "Risk" (1 to 5) that a sale lot would meet the requirements of the white/pastel trade (Burbidge, McInnes and Foulds 1991; Burbidge, McInnes and Foulds 1994; Burbidge and McInnes 1994). This calculation is based on the following objective information: wool type and description, sex, age, crutching and crutch/shear interval.

Table 12.1 For each Risk Level, the mean df/kg and percentage of lots with ≤100 df/kg. Source: Burbidge and McInnes (1994).

Risk Level	No. Lots	Mean df/kg	% Sale Lots with ≤100 df/kg	Probability	95% CL
1	5	43	100	1.00	0.54
2	35	72	77	0.77	0.62
3	56	112	68	0.68	0.56
4	35	254	43	0.43	0.28
5	30	802	20	0.20	0.09

The 95% Confidence Limit (CL) value means that a lot chosen at random from within a Risk Level will have a certain probability of its dark fibre content being <100 df/kg. For example, a lot chosen from Risk Level 2 has a 62% chance of having a dark fibre count <100/kg, whereas a sale lot chosen at random from Risk Level 5 has a very low chance (9%) of having a dark fibre count <100/kg.

Contact with exotics

Additional information as to whether the Merinos had been mated to, reared or run with exotic sheep (or their crosses) was added to the scheme enabling the calculation of the DMFR Rating. This involved validation trials (Hansford 2003) to evaluate any differences between exotics sheep breeds (See Figure 12.5) as well as whether different forms of "contact" affected the levels of contamination (see Figure 12.7).

Figure 12.6 shows little difference in the dark and medullated fibres measured in the greasy wool sample for each exotic breed. Note; Dorper includes both traditional and white Dorper.

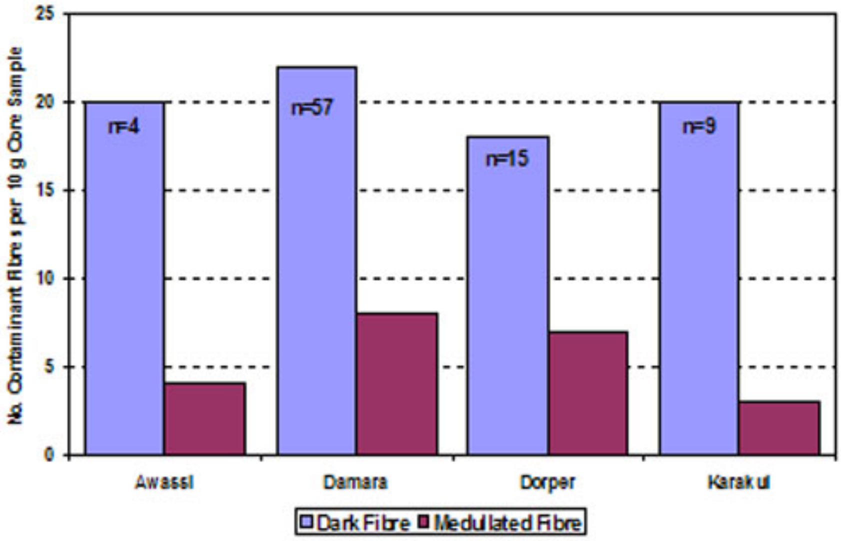


Figure 12.6 Dark and medullated fibres (no. fibres/10 g) for Merino sale lots representative of contact with different exotic breeds. Source: Hansford (2003).

Figure 12.7 highlights the difference in contamination of Merino wool between contact with exotics and running next door to them. That is, physical contact is critical to the transfer for between Merinos and exotics, with the "loose" fibres entwining with the Merino wool fibres.

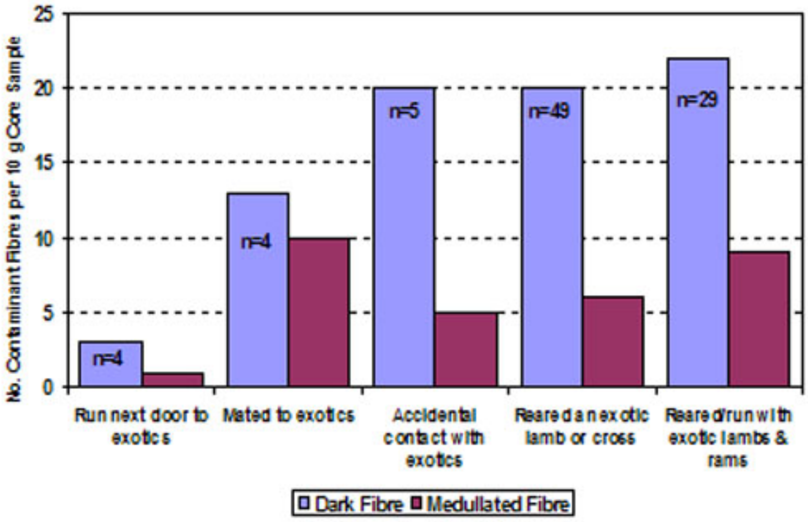


Figure 12.7 Dark and medullated fibres (no. fibres/10 g) for Merino sale lots representative of different forms of contact with different exotic breeds. Source: Hansford (2003).

Dark and medullated fibre risk scheme

After combining information related to both dark fibre risk and contact with exotics, the DMFR Risk tree is composed as per Figure 12.8 (Hansford and Australian Wool Industry Working Group 2003). The DMFR Scheme, applicable to Merino fleece and piece wools, has a scale of 1 to 6, with Level 6 applicable to Merinos that have been in contact with exotics. Risk Levels 1 and 2 are considered suitable for sensitive end-uses.

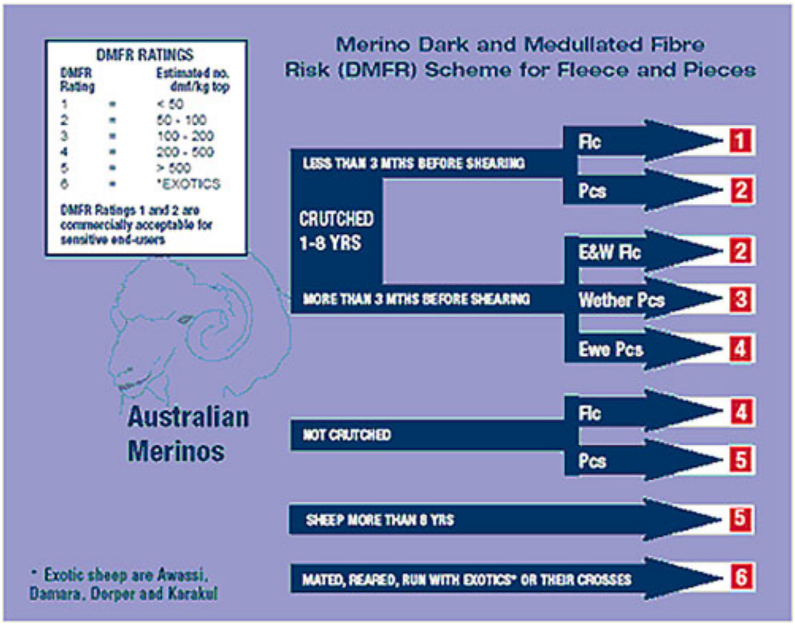


Figure 12.8 Dark and Medullated Fibre Risk Tree. Source: AWI (2005).

All information is collected on a Classer's Specification or separate declaration form (see Figure 12.9) and the DMFR calculated at centrally at AWTA Ltd (Hansford 2003).

Mob Number	Bale Ranges		WOOLGROWER DECLARATION for CALCULATION of DARK and/or MEDULLATED FIBRE RISK (DMFR) (DMFR Declaration is applicable to Merino Fleece and Piece Lines only)				
	From	To	Contact[1] with Exotic[2] Breeds (Y/N)	Sex (Code)	Age/ Shearing (Code)	Crutched (Y/N)	If crutched, was it within 3 months of shearing (Y/N)
OWNER/MANAGER SIGNATURE:						DATE:	

SEX CODES **E** – Ewes **W** – Wethers **R** – Rams **M** – Mixed E/W/R	**AGE/SHEARING CODES** **1** = 1st shearing **2** = 2nd shearing to 24 months **3** = 3 years **4** = 4 years etc. **Describe Mixed Years** e.g. 2-3, 4-6, 2-7 etc.	**Note: OWNER/MANAGER must COMPLETE and SIGN section above (within heavy bold lines) to obtain a DMFR Rating.** 1. Contact is defined as mated to, run in the same paddock as or reared with exotic sheep/lambs or their crosses. 2. Exotic breeds (those that shed dark and/or medullated fibres) with an AWEX Breed Risk Rating of 5, i.e. Awassi, Damara, Dorper and Karakul.

Figure 12.9 Woolgrower Declaration for the determination of DMFR Rating. Source: AWI (2005).

12.3 Measurement of wool origin contamination

Urine-stained, pigmented and medullated fibres are all quantified in terms of the number of each fibre type observed in a sample of fibres. The cleanliness of a combed sliver is measured according to IWTO Draft Test Method 24-01(IWTO 2001); however, this method only counts the number of fibres in a known weight of sample but does not differentiate between the fibre types.

Dark and medullated fibre guidance test

In industry, wool is inspected to quantify the dark fibres; however, early methods were not robust. An improved method for detecting dark fibres in raw wool or top was presented to IWTO by Roger Foulds and colleagues presented to the International Wool Textile Organisation in 1983. The method involved balanced illumination whereby white fibres in a web become invisible when light is shone above and below it. At the same time, all the dark fibres are visible. This method for detecting dark fibres became known as the CSIRO Dark Fibre Test method.

More recently, CSIRO, South Australian Research and Development Institute and AWTA Ltd extended this methodology to enable detection of both dark and medullated fibres (Sommerville 2001). A critical aspect in the development of the DMF Test was the immersion of the scoured and carded wool sample in a bag containing Benzyl Alcohol. This solvent has a similar refractive index to wool allowing it to become transparent, with little reflection. Thus, when viewed with a white background under balanced illumination, the dark fibres absorb incident light and become visible. In contrast, medullated fibres reflect the incident light and appear white when illuminated from above against a black background (see Figure 12.10).

Figure 12.10 Dark and medullated fibres are made visible with appropriate lighting. The fibres can then be counted. Source: Sommerville (2001).

The equipment described above (see Figure 12.11) allows the manual measurement of the dark and medullated fibre content of a scoured and Shirley analysed (carded) core sample. While the capital cost is low, the test is labour-intensive and thus costly.

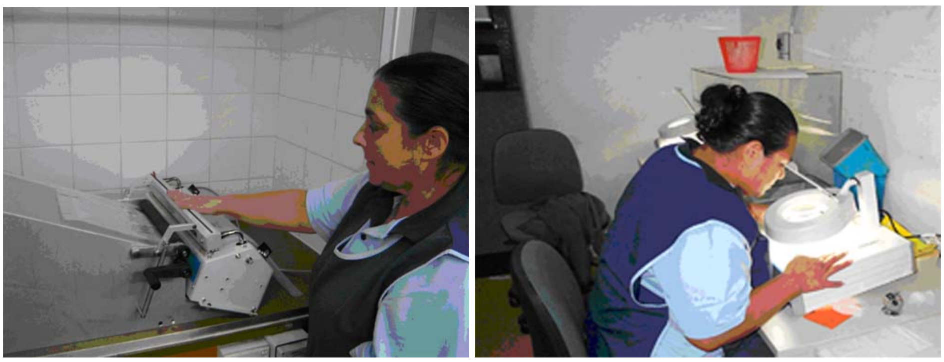


Figure 12.11 Dark and medullated fibres are made visible with appropriate lighting. The fibres can then be counted. Source: Sommerville (2001).

The DMF guidance test is not certified, as the measurements do not currently meet the stringent standards required for IWTO Test Method status. Future research and development is required to automate this test and facilitate image analysis measurement and in the future, gain IWTO Test Method accreditation.

Factors affecting DMF measurement

Reference scale for the colour of dark fibres

As mentioned previously, urine-stained and pigmented fibres vary in colour (Foulds, Wong and Andrews 1984). For urine- stain, fibres change in colour from pale yellow to nearly black in response to the time of exposure to urine, whereas pigmented fibres may differ in colour depending on the amount and dispersion of melanin present. This has commercial significance, since fibres that are pale or light in colour (e.g. yellow), may not be considered a problem. Conversely, brown to black fibres create a commercial fault that needs to be remedied.

In 1982, Foulds Wong and Andrews (1982) developed a reference scale to categorise the "colour" of the fibres that are commercially important. This eight step scale from 0 (white) 8 (black) is presented in Figure 12.12. The scale progressively darkens from yellow at 1 through to dark brown at 7, with fibres with value greater than 4 are considered as a commercial fault and are economically important. Note: Stains such as canary stain, dag, pen stain, etc., whose value is usually less than 4 can be ignored, as the fibre colour is too pale to be important to the manufacturer.

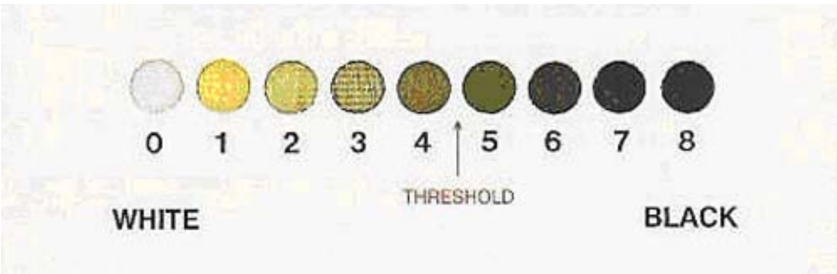


Figure 12.12 Reference scale for the colour of dark fibres. Source: CSIRO (1992).

Threshold values for medullation

Balasingam reviewed medullation in relation to testing in 2005. As indicated in Figure 12.4, in structure, medullation may be unbroken (lattice type or simple unbroken) or broken (interrupted or fragmented). Most medullated fibres have a chalky white appearance even after dyeing, as well as different optical properties which affect their appearance in the fabric.

Medullated fibres, which are generally coarser in diameter than normal wool, may be classified as kemp, highly medullated fibres or flat fibres. These classifications, which take into consideration fibre shape, intrinsic strength and the type of medulla, are thought to be important when measuring visually objectionable fibres (i.e. those that cause commercial concern). Little is known of the behaviour of medullated fibres during processing and consequently, their persistence through to fabric. Further research is therefore required to determine the relationships between the measurements made on a greasy core sample with those in the top and fabric.

Sampling of greasy wool for DMF

In terms of applicability to core testing, the DMF testing is dependent on the distribution of DMF within a bale (Sommerville 2001; Hansford 2003). In circumstances where Merinos have been in contact with exotic breeds or their crosses, this contamination is randomly distributed through the fleece and bale; hence core sampling provides a representative sample. In contrast, the test is not applicable to isolated urine-stain, pigmentation or medullation, where the faults are found in discrete locations in a fleece/bale, i.e. the core sample is not representative.

12.4 Contamination of non-wool origin

This section outlines the origin of non-wool contamination found in Australian wool (Abbott and Blanchonette) 1996a; (Abbot, Blanchonette and Heintze), 1996b. These contaminants include wool packs and farm objects including baling twine, mill packs and mill objects.

The problem of non-wool contamination

The problem caused by non-wool contamination depends on how the contaminant breaks down during processing:

- During manufacture, plastics are often heat-drawn to increase strength. When tension is applied, they fibrillate or split lengthwise into many fine fibres. If the contaminant fibrillates to a shape and size that mimics the wool fibre, it may end up in the finished product, e.g. fabric. In this instance the manufacturer faces costs associated with inspection and removal as well as a delay in delivery
- Larger items are often detected prior to processing, for example using metal detectors before carding, and thus cause fewer problems to the manufacturer. However, if such items are not detected, major damage can occur to machinery.

Within-bale contamination generally occurs on the farm. It finds its way into wool either prior to, or during shearing. Wool pack material also causes contamination; however, this usually occurs once the bales have left the farm, i.e. during handling, sampling or transport.

Within-bale contamination

The most common within-bale contaminants are hay bale twines and woven fertiliser or seed bags, which are made from heat-drawn Polypropylene (PP).
Less common items include plastic film and tapes that are without heat (are

difficult to fibrillate and hence tend to fall out during processing); non-scourable branding fluid, hairs, bristles, cigarette butts, clothing or towels, other textile fibres and threads, string, wire, feathers as well as various solid objects made from plastics (e.g. ear-tags) or metal (e.g. bale fasteners) etc.

Figure 12.13 Farm object found as within-bale contaminants.
Source: Blanchonette (2005) with permission.

Woolpack contamination

The primary materials used to pack Australian wool were firstly, jute and followed by high-density polypropylene (HDPE). While HDPE does not fibrillate as readily as PP, it can still cause contamination problems. Both jute and HDPE cause problems not dissimilar to medullated fibre contamination. They do not take up dyes in the same way as wool and thus are often not detected until after dyeing.

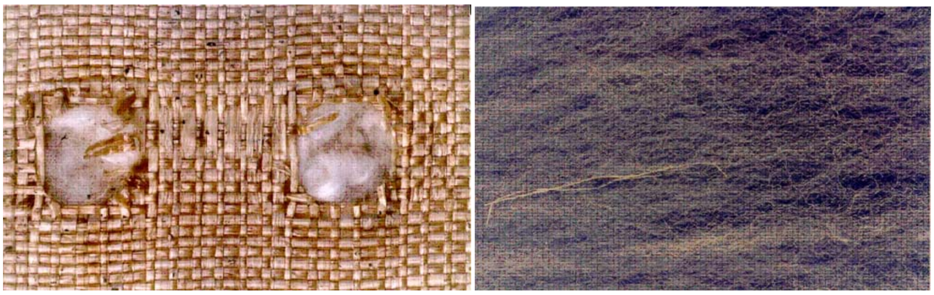


Figure 12.14 Wool pack damage and fibrillated wool pack in a card web. Source: Blanchonette (2005).

Today, it is compulsory to use nylon wool packs. AWEX regulates entry and performance of the nylon 6 packs that are imported to Australia. Nylon is not considered a contaminant, because it dyes a similar shade to wool.

Mill contamination

Non-wool contamination is not solely the provenance of farms. Activities in processing mills also result in problems with foreign objects being found in wool. Early stage processors pack semi-processed wool in a variety of PP and Polyethylene (PE) packaging that may contaminate wool during handling. In addition, dyed wool or other textile fibres or thread along with processing machinery parts such as combing pins or spikes, are also found.

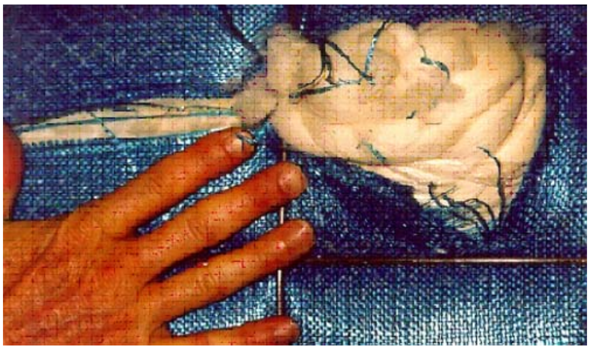


Figure 12.15 Mill pack damage. Source: Blanchonette (2005).

Limits for non-wool contamination

Processors expect zero non-wool contamination, e.g. PP baling twine. AWTA Ltd has a contamination screening service as part of the core testing procedure, contaminants may be identified. If found, the lot will be withdrawn from sale. In these circumstances, the cost of handling the bales to remove the contamination may be passed on to the producer. Buyers have the right to reject a purchase if the contamination is found after sale but before shipment.

The extent of non-wool contamination

Two global surveys of funded by AWC/AWI and conducted 10 years apart have quantified the status of non-wool contamination originating from Australian wool (AWC 1993; 2003). The frequency of non-wool contamination has decreased by approximately 50% between 1993 and 2004.

In 1993, approximately 50% of the non-wool contamination comprised within-bale contaminant (or farm objects) and 50% was attributable to the wool packs. By comparison, little contamination was of mill origin. In 2004, these values had changed to approximately 90% farm objects, 4% wool packs and 6% mill packs and mill objects.

Within-bale contamination
In 2003, the most common within-bale contaminants were haybale twine (61%), fertiliser bags (14%) and keratin feathers (8%). Indeed, hay bale twin contamination (measured per tonne of clean wool) was three times higher than in 1993; whereas fertiliser bag contamination was 50% less.

Woolpack contamination
In 2003, wool pack contamination totalled 4% of the total contamination. This decrease was largely attributable to the replacement of HDPE packs with those made from nylon. Of this 4%, 80% was from HDPE packs (which had not been totally phased out), while 20% was nylon. In this instance the nylon contamination was found as large pieces in early stage processing, not as a fault in the fabric.

Mill contamination
Of the total contamination, mill packaging or mill objects made up 6% in 2003.

Readings [3]

The following readings are available on web learning management systems

1. AWEX, 2004, AWEX Code of Practice - Preparation of Australian Wool Clips – The Woolclasser, Australian Wool Exchange Ltd., Sydney NSW, Australia.
2. AWI, 2003, 'The AWI 2003 Non-wool contamination survey,' Australian Wool Innovation, Sydney 2003.
3. AWTA Ltd, CSIRO and AWI, 2004, 'Development of an improved test for detection of dark and medullated fibres in presale core samples,' *Proceedings. of IWTO,* Technology and Standards Committee, Raw Wool Group, Report No. RWG 05, Shanghai Meeting, November 2004.
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5. Hansford, K.A. and Australian Wool Industry Working Group, 2003, 'The development of a quantified risk factor for the presence of dark and/or medullated fibres in Australian Merino wool,' *Proceedings. of IWTO,* Raw Wool Group, Report No. RWG07, Istanbul meeting, November 2003.

Summary

Summary Slides are available on web learning management systems
This topic has been developed to enable students to gain an understanding of the different forms of contamination of the Australian wool clip. It describes the two main sources of contamination – wool and non-wool. Methods to minimise contamination *per se*, as well as strategies to minimise the risk of purchasing contaminated wool are also described.

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Glossary of Terms

AWEX	The Australian Wool Exchange is the national body responsible for market reporting of wool auction sales in Australia. AWEX also administers woolclasser registrations and maintains the Code of Practice for Woolclassing
AWTA Ltd	Australian Wool Testing Authority Ltd is responsible for the independent testing of raw wool and issues test certificates
Bale or Pack	Wool is compressed into packs to reduce space for storage and transport, with the package a standard size to fit an order for shipment. It may be a farm bales, dumped or unitized. The farm bale is a rectangular shaped package made from Jute, HDPE or Nylon, generally weighing 100 kg to 200 kg. Australian wool is now only packaged in nylon to minimize problems with dyeing if wool is contaminated by the pack material
Dark and Coloured Fibres	The darkness of the black or coloured (brown) fibre is classified against a standard reference scale. The numbers of fibre with a higher degree of contrast then the threshold level are counted as dark fibres if the length is over 10 mm. Other coloured fibres below 10 mm are classified as foreign fibres. Results are expressed as the number of coloured fibres per 100 g of sliver
Black or Grey Wool (Y)	AWEX ID Scaled Qualifier. Any wool that is not white, but not necessarily black. Grey or brown wool in colour is often assessed as black
Catalogue	Printed list, prepared by the selling broker, showing the lot number, owner's brand, description of the wool and the number of bales in each lot. Catalogues are supplied to buyers for valuing purposes and to growers when they inspect their wool
Clip	The production of wool from one shearing (or one season's yield of wool)
Core Sample	A representative sample of raw wool obtained from each bale in a lot by coring techniques
Core Sampling	A method of taking representative samples from bales or packs of textile fibres obtained by inserting a coring tube (usually 2 cm in diameter) driven by hand or machine into each package. Core samples can be used for the determination of yield and fibre diameter, but not length. Mini-core sampling is the term applied to small scale sampling, generally using a 2 mm diameter core tube
Core Testing	Consists of testing a known quantity of wool for yield, fibre diameter and vegetable matter content and type; the sample is extracted from a bale of greasy wool, by means of a core or tube. Core tests are usually conducted prior to sale (pre-sale
Crutchings (C or CRS)	AWEX ID Wool Category. Wool removed from the breech, tail or hind leg regions of a fleece, being of lower value. It is short and may be discoloured from urine or dag stain
Crutch/Shear Interval	The amount of time, usually in months, between crutching and shearing. For example, if the mob was crutched in February and shorn in the following August, the crutch/shear interval is 6 months
Dark and/or Medullated Fibre Risk (DMFR) Scheme	A voluntary vendor declaration for the risk of dark and/or medullated fibre contamination of Merino wool was introduced to Australia in July 2004, with the results reported in sale catalogues and test certificates. The risk scheme is based on the CSIRO concept of a stained and pigmented fibre risk factor for Merinos (Dark Fibre Risk Scheme), but extends it to include the dark and/or medullated fibre risk incurred when Merino sheep come in contact with "exotic" sheep or their crosses. Exotic sheep are the breeds Awassi, Damara, Dorper and

	Karakul
Dark Stain (S)	AWEX ID Scaled Qualifier. Staple or locks of wool, from the breech area pf ewes and belly (pizzle) area pf rams and wethers, heavily contaminated with urine-stained (black or coloured) fibres
Dump	the process of compressing bales, usually greasy wool, to a density exceeding 500 kg/m^3 and restraining them with bands or wires. Commonly, three bales are dumped to form a tri-pack
Ewe	A female sheep
Exotic Breeds	The term applied to breeds introduced to Australia, including Awassi, Damara, Dorper and Karakul. They are characterised by a fleece that seasonally sheds dark and/or medullated fibres, and as such have been given a high AWEX Breed Risk Rating of 5. Contact between exotic breeds and Merino sheep increases the risk of dark and/or medullated fibre contamination of Merino wool
Fault	Contamination, especially vegetable matter, in greasy or semi-processed wool
Fleece Wool: (F or FLC)	AWEX ID Wool Category. The highest quality wool derived from the fleece, with lower quality (shorter, more contaminated) parts removed
Grab or Display Sample	The grab sample taken from a single lot placed into a display box
Grab Sampling	A method of taking a representative samples from packages of textile fibres. A jaw is driven by a machine into the packages and when withdrawn brings out a sample of fibres. Grab samples can be used to measure length and strength
IWTO	An international forum for establishing standardised test procedures (IWTO Test Specifications), regulations governing the use of these procedures (IWTO Regulations), and procedures for arbitrating disputes over commercial transactions involving raw wool, wool sliver and wool yarns (the IWTO Blue Book). IWTO is pivotal in providing a technical and commercial framework for international and intra-national trade involving wool. Representation within IWTO is via National Committees appointed by the Wool Industry associations within member countries
Kemp (P)	AWEX ID Scaled Qualifier. Any parts of wool containing medullated fibres. Kemp are hard, brittle opaque medullated fibre found on the fleece of some sheep, usually coarser and shorter that the wool fibres that it is associated with. It is shed after growing for a limited time and may lie loose in the fleece. Often found on the head and on the legs
Lot, Sale Lot or Line of Wool	Any number of bales of wool, of similar mass and dimensions, prepared for sale as a single parcel in accordance with accepted trade practices
Medullated Fibre	Fibres possessing a medulla or a core of air-filled cells. Under the microscope, this structure appears spongy. When the medulla is coarse, the fibres are hairy, harsh in handle and possess irregular dyeing properties
Merino (M)	AWEX ID Breed. Merino wool is white and includes the SAMM and Dohne Merinos. The Merino breed dominates sheep production in Australia. Through careful breeding, the Australian Merino is recognised world-wide for it fine diameter, length and cleanliness
Mob	A group of sheep that have been run under exactly the same conditions for the full wool growing season, for example, a mob of ewes that have been run in the same paddock, drench and mated/lambed at the same time

Piece Wool or Pieces (P or PCS)	AWEX ID Wool Category. Piece wool is the frib or sweaty edges that are skirted from the edges of the fleece. It ranges from inferior, coloured wool to higher quality 'broken' wool, but does not contain 'necks', 'bellies', 'stains' or 'locks'
Ram	A male sheep that has not been castrated (or desexed)
Sample	A small separate part of textile fibres or products representative of the fleece, lot or consignment
Shearing	The removal of the fleece of a sheep by the use of an electric handpiece or manual shears
Skirtings	Portions of the external edges of a fleece removed by the classer after shearing. Skirtings primarily form the piece lines of a clip. Skirtings are further categorised depending on length (carding and combing length) and cleanliness. High quality skirtings are referred to as broken
Specification (or Test Method)	The document that prescribes the requirements with which a product or service has to conform (e.g. IWTO or Australian/New Zealand Standard)
Stain (S or STN)	AWEX ID Scaled Qualifier. This is wool that will not scour white. Stains are commonly caused by urine, bacterial action, chemical treatments, branding fluids, vegetable matter and blood
Test	A set of measurements made on a sample of raw wool, in full accord with a specification (e.g. IWTO)
Test Certificate	A certificate for a lot of wool resulting from the testing of samples in accordance with the relevant Test Regulation (e.g. IWTO) and Test Specification (e.g. IWTO). Test results may include measurements of yield, diameter, vegetable matter base, staple length and strength and colour
Test House	A laboratory which carries out tests in accordance with the current IWTO Specifications and Regulations. In order to issue an IWTO Test Certificate, the laboratory must be a licensed laboratory (see AWTA)
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 characterized by the following properties
Water Stain (N)	AWEX ID Scaled Qualifier. Parts of a fleece that have been stained by prolonged exposure to water resulting in a pale green or brown colouring
Wether	A male sheep that has been castrated as a lamb