A Travel Report
presented to
RIRDC

The 3rd International Cashmere Determination Technique Symposium, China

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Foreword

Australian cashmere is different in many characteristics to traditional Cashmere. As a result international textile trends could define Australian cashmere as off-type or inferior cashmere and already some international scientists have proposed that Australian cashmere be classified as 'crossbreed cashmere'.

The Chinese cashmere industry which is the world leader in production and processing is endeavouring to adequately define the cashmere fibre. To this end the 3\textsuperscript{rd} International Cashmere Determination Technique Symposium was organised and held in China including objectives to discuss recent analysis on the features of cashmere fibre using the Scanning Electron Microscope. One hundred and fifteen international scientists attended.

The Corporation supported Dr B McGregor the author of this report on the presentation of three papers at the Symposium. Some of the information presented was from previously funded RIRDC projects. New proposals for measuring cashmere crimp and cashmere fibre lengths were made by Dr McGregor at the Symposium.

This project was funded from industry revenue which is matched by funds provided by the Australian Government

This report, an addition to RIRDC's diverse range of over 1500 research publications, forms part of our Rare and Natural Animal Fibres R&D program, which aims to facilitate the development of new and established industries based on rare natural fibres.

Most of our publications are available for viewing, downloading or purchasing online through our website:

- purchases at www.rirdc.gov.au/eshop

Peter O'Brien
Managing Director
Rural Industries Research and Development Corporation
Summary

China and the region of Inner Mongolia is the world leader at producing and processing cashmere. The largest and best cashmere goat breeding farms are located on grasslands in Inner Mongolia. Many leading cashmere processing companies have relocated from Europe and Japan by establishing joint venture companies with the latest modern equipment.

Travel was undertaken to:
1. Visit the leading cashmere processing company Erdos Cashmere Group, Eerduosi City, Inner Mongolia.
2. Inspect the facilities of the China National Engineering and Technology Research Centre for Cashmere Products.
3. Attend the 3rd International Cashmere Determination Technique Symposium.
4. Present scientific papers on Australian cashmere research.
5. Establish dialogue about cashmere research with the aim of establishing professional contact for joint research and further interchange of knowledge and skills.

The conference scientific presentations were attended by 115 scientists with 65 registered for the cashmere determination and measurement workshop. The author prepared four scientific papers addressing priority issues for the conference and three were presented. Important presentations by Chinese scientists addressed the critical issue of cashmere fundamental fibre surface properties. New knowledge in classifying cashmere fibre morphology was explained. New potential methods were also discussed but need further research. The evidence for a new test method for determining pilling propensity in cashmere fabrics was presented. New proposals for measuring cashmere crimp and cashmere fibre length were made by this author. Suggestions to overcome marketing difficulties of Chinese cashmere were also made.

Very informative visits were made to the new China National Engineering and Technology Research Centre, to the Erdos Cashmere Group Industrial Park and associated subsidiaries and to the Inner Mongolia Arbls White Cashmere Goat Breeding Station situated 235 km west of Eerduosi City.

Benefits include the following:
1. Opportunity to publish cashmere research in the best international cashmere forum.
2. Exposure of Australian science and technology to the Chinese cashmere industry.
3. Networking with leading Chinese and International cashmere textile scientists with a good potential to establish further working contacts and collaboration.
4. Up date on developments in cashmere textile and measurement science.
5. Learning opportunity on new processing methods and equipment.
6. Production update from one of the leading cashmere studs in Inner Mongolia.

The following activities are recommended:
1. Maintain awareness of future International Cashmere Determination Technique Symposia and make plans to attend.
2. Encourage submission of technical papers to future International Cashmere Determination Technique Symposia.
3. Develop opportunities for future research collaboration.
4. Consider hosting visits by Chinese scientists if they visit Australia for other functions such as IWTO meetings.
Acknowledgments

The Victorian Department of Primary Industries is thanked for providing approval for Dr. B. McGregor to undertake the study tour. Staff of Erdos Cashmere Group Ltd is thanked for making the author very welcome during his stay in China. Ms Meng Linghong (Cathy) has been thanked for being a very efficient and skillful translator. Erdos Cashmere Group Ltd is also thanked for translating English scientific papers into Chinese.

About the author

As a Senior Research Scientist, Dr. Bruce McGregor B.Agr.Sc.(Hons), Ph.D., Advanced Cert. Textile Technology, has focussed on improving the production and quality of speciality animal fibres. His long interest in the marketing and processing of natural fibres has included Ph.D. studies focussed on the quality of cashmere and its influence on textile materials produced from cashmere and blends with superfine (16 µm) wool. His interests include nutrition and farm management, fibre quality, fibre production and textile quality. He has published a number of other RIRDC reports that are available on the RIRDC internet site.
Chapter 1 Objectives of visit

1.1 Background
The Australian cashmere industry and the RIRDC R&D Plan for the Rare Natural Fibres Program visualise an expanding cashmere industry. For this expansion to occur, cashmere production has to be perceived by land-managers as being attractive. The attractiveness of any industry is related to many attributes including financial returns, compatibility with existing enterprises, the status of the product and the technical complexity of marketing and production.

Much work was undertaken on the attributes of cashmere production during the 1980s. The cashmere goat notes in the recently published Australian Goat Notes (Anon 2001) rely heavily on production data from goats born during the mid 1980s with little new information on quality or production levels of current Australian cashmere goats and little on the processing attributes of Australian cashmere. No independent evaluation of the cashmere production capability of leading flocks has been undertaken since 1989. Since this date, it is widely assumed that there has been a change in cashmere productivity and quality as a result of widespread culling related to the following important issues:

- The price decline during the 1990s focussed the minds of farmers on removing animals of low productivity and poor economic return.
- The industry undertook extensive training and communication activities to improve cashmere quality attributes. In particular, the industry attempted to rid itself of “off type” cashgora fleeces (see McGregor, 1997, for a discussion of these issues).
- Leading breeders have used the cheaper and more available objective fleece testing services to identify sires and have applied positive selection pressure to improve cashmere production and quality.

Taken together, these developments should have contributed to increased cashmere production and made investment in the industry more attractive.

Recently completed research on the textile attributes of Australian cashmere has shown that Australian cashmere can be processed to produce cashmere tops in the top 25% of those available internationally (McGregor 2001a,b, 2002). Australian cashmere is different to traditional cashmere, it has less fibre curvature (crimp), it is softer, longer, whiter and has more tensile strength. It is also perceived to be more lustrous, in part perhaps because the raw cashmere has less naturally occurring contaminants such as grease, suint, soil and vegetable matter (McGregor 2003).

The price of cashmere tops increases as the fibre length (Hauteur) increases and the fibre diameter decreases. It is therefore vital that the Australian industry improves its production, preparation and processing procedures to maximise marketing opportunities and economic returns. Generic processing of Australian cashmere (DAV 98A, McGregor 2001a,b, 2002) established the first benchmarks for the local industry. The establishment of on shore Australian cashmere processing has provided a unique opportunity to develop relevant processing benchmarks, designed for higher value worsted processing of cashmere, that have real meaning for Australian processors and producers (DAV 200A). This project has established a much greater body of objective measurement data on the processing performance of Australian cashmere.

However international trends have been focussed on defining cashmere to prevent substitution and contamination by cheaper animal and man-made fibres. As Australian cashmere is different to traditional cashmere, it is possible that Australian cashmere may be defined as off type or inferior cashmere. This idea is not as far flung as it may seen. Based on certain fibre properties of cashmere including fibre diameter and fibre cuticle scale dimensions measured using the scanning electron microscope (SEM), the scientists in Germany have proposed a system to define and classify cashmere (Phan et al. 1991, Phan and Wortmann 1996). As these scientists obtained greater experience with the SEM technique, they have encountered some difficulty in clearly separating cashmere fibres from different origins (eg Phan et al. 1991 p 11 and Phan and Wortmann 1996 p 54). Without consulting the Australian industry these German scientists have proposed that “the so-called Australian cashmere” (Phan et al. 1991, p11) be classified as “crossbred cashmere” (Phan and
Wortmann 1996). Such a proposal is based on a large degree of ignorance of the production system and processing performance of Australian fibre but if enforced in some way it would spell the death knell of our industry.

As the Chinese cashmere industry is expending a large effort to adequately define cashmere in order to protect itself from unscrupulous activities and contamination it is essential that Australians participate at their International forums to both understand their research and position and to explain our science. There is also the opportunity to expand and extend their research to encompass our fibre.

The conference also provides a unique opportunity to visit the leading processing company Erdos Cashmere Group, which is hosting the conference. Many of the topics on the program are highly relevant to our recent research into Australian cashmere and visits to the Erdos factory and laboratories will provide an insight into their capabilities and future direction. This conference appears to be an excellent opportunity to learn from Erdos specialists. This travel is related to the recent RIRDC project DAV 200A.

This report describes the objectives and outcomes from a 6 day study tour during September 2005.

1.2 Project Objectives
The primary objectives of the project to visit China were to:
1. Visit the leading cashmere processing company Erdos Cashmere Group Ltd.
2. Inspect the facilities of the China National Engineering and Technology Research Centre for Cashmere Products.
3. Attend the 3rd International Cashmere Determination Technique Symposium.
4. Present scientific papers on Australian cashmere research.
5. Establish dialogue about cashmere research with the aim of establishing professional contact for joint research and further interchange of knowledge and skills.

1.3 Project Itinerary
The itinerary is shown in Table 1.1.

Table 1.1. The itinerary for travel to China

<table>
<thead>
<tr>
<th>Date</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuesday 20 September</td>
<td>Travel Melbourne to Beijing 730 to 2330 hrs</td>
</tr>
<tr>
<td>Wed 21</td>
<td>Travel Beijing to Baotou, Inner Mongolia, Travel Baotou to Eerduosi. Conference Registration. Inspection of Erdos Cashmere Group, spinning, weaving, garment construction, show rooms.</td>
</tr>
<tr>
<td>Fri 23</td>
<td>3rd International Conference, 800 – 1800 hrs, workshops and papers Inspection China National Engineering and Technology Research Centre for Cashmere Products.</td>
</tr>
<tr>
<td>Sat 24</td>
<td>3rd International Conference, 700 – 1800 hrs, Factory visits, Visit Inner Mongolia Cashmere Goat Farm, Etuoke County</td>
</tr>
<tr>
<td>Sun 25</td>
<td>Travel Eerduosi City 700 hrs to Baotou, Beijing, Shanghai to Melbourne.</td>
</tr>
<tr>
<td>Monday 26</td>
<td>Arrive Melbourne 630 hrs</td>
</tr>
</tbody>
</table>
Chapter 2 The 3rd International Cashmere Determination Technique Symposium

2.1 Background
The conference scientific presentations were attended by 115 with 65 registered for the cashmere determination and measurement workshop. Most people came from China with many employed by leading cashmere processors, government agencies and companies concerned with the measurement or regulation of trade in textiles. There were also academics employed in various university departments of textiles. Overseas papers were provided by scientists from the U.S.A., Argentina and Australia.

The advertised objectives of the conference were:
1. To discuss the recent trends in international cashmere/wool determination techniques. (e.g. colored fibre determination, luster test, color stripped fiber determination and crimp determination etc.).
2. To examine the use of hand arraying length and Almeter length determination of cashmere fibres.
3. To discuss recent analysis on the features of cashmere fibres using Scanning Electron Microscope.
4. To examine the uncertainty assessment of test results.
5. To discuss recent research on the fuzzing & pilling Test Method for cashmere knitwear.
6. To examine the comparison analysis of Ulster Analyser (capacitance) and CTT Yarn Analyser (made in the USA).
7. To discuss the assessment of color difference of textiles.
8. Other topics related to cashmere/wool determination technique.

The conference was held at the Tianjiao Hotel, which is owned by Erdos Cashmere Group and was situated within 400 m of many of the Erdos subsidiary companies within Eerduosi City. Until recently Eerduosi City was known as Dongsheng and Erdos Cashmere Group was known as the Donseng Cashmere Sweater Factory.

2.1.1 Presentations by grantee
The author prepared four scientific papers addressing issues of direct relevance to the conference objectives. These papers were accepted and translated into Chinese. English versions of these papers are provided in Chapter 4. The organisers arranged for three of these papers to be presented to the scientific session. These presentations addressed the conference objectives 1, 2 and 5 relating to cashmere crimp determination, hand array length and Almeter length and pilling measurement of cashmere knitwear. The organisers also provided 15 minutes for a brief presentation on the fourth paper that addressed conference objectives 1, 2, 6 and 8 relating to a new method of measuring fibre length in cashmere and a comparison with existing methods.

There was some discussion following the presentation on the paper “Relationship between Baer diagram hand array length and Almeter length measurements for dehaired cashmere” regarding the size of operator error in Baer diagram mid length estimates. I was advised that the operator error had been determined in extensive trials in China and was 2 mm. In response to my question to the audience I was informed that test houses have determined the operator error as 2 mm.

2.1.2 Other presentations
2.1.2.1 Identification of cashmere fundamental fibre surface properties
The major presentations from staff of Erdos and various inspection services in both the scientific and workshop sessions concerned the identification of cashmere fibre and the determination of substitute or contaminant fibres particularly fine wool fibres. This issue is a major concern to all participants along the supply chain from purchasers of raw fibre, textile companies, testing agencies and importers.
Current best practice in the identification of animal fibres is to count and measure the size and dimensions of the cuticle scales. The scientific authorities and best practice for these test methods are based on German research in the 1980s and 1990s.

It has been known for many years that some cashmere fibre is traded with contaminants of raw wool, camel, yak or man-made fibres. In both raw cashmere and in cashmere textiles, these other fibres are generally easy to identify. However in recent years there have been three trends that have made the identification of contaminant fibres more difficult:

1. The chemical modification of wool fibres in particular but also some cashmere fibres. This modification removes or covers the fibres outer cuticle scales so making it difficult to identify or measure the scales. In recent years many Chinese textile companies have installed facilities that allow chemical modification of wool for “shrink-proofing”.
2. A practice of processing wool from more primitive types of sheep fleeces where down type fine wool is extracted by dehairing. This wool has been mixed with cashmere or sold as cashmere wool. China has many breeds of sheep with the primitive wool fleeces.
3. A more strict interpretation of the acceptable guidelines. For many years the IWTO guidelines for textile trade have allowed a 5% margin for “impurity” fibres. The EU allows 3% whereas the USA specifies 0%.

One consequence of the heightened sensitivity to impurity fibres is where there is an overlap or uncertainty about the origin of a fibre it may be classified by some testing houses as ‘unknown’ fibre. I inspected garments in wholesale shops in Eerdusio that had labels showing 95% cashmere, 5% unknown. Some test houses call this fibre 100% cashmere. There was long and animated discussion about whether 95% cashmere is “pure”. Textile manufacturers are rightly upset if orders are rejected because a test house “identifies” unknown fibres.

Yang, G., Fu, Y., Hong, X. and Wang, C. Discussion on cashmere fibre identification technique by SEM and LM. Proceedings 3rd International Cashmere Determination Technique Symposium: 189-205.


The book includes 101 SEM and 21 other images based on over 10,000 SEM analyses. The micrographs are based on 105 lots of cashmere samples taken from the 16 main producing regions and the 3 large stud farms in China. These samples were collected in 2002 of which 79 samples were provided by Erdos, 11 by Tianshan Wool Textiles Group (Xin Jiang), 10 by King Deer Cashmere Group with each sample weighing 3 kg or raw cashmere. Following scouring, 60 fibres from each lot were measured under the SEM. The scouring yields for some of the fibre lots are provided in Table 2.1.

The data set has a mean fibre diameter of 15.2 µm, CVD 22.4%. Cuticle scale height averaged 0.35 µm (range 0.30 to 0.40 µm) and a cuticle scale frequency of 60/mm (range 57 to 64/mm). The scale height for cashmere of mean fibre diameters of < 18.0 µm averaged 0.34 µm and for cashmere with a mean fibre diameter 18.0 to 25.0 µm scale height averaged 0.36 µm. The ratio of (mean fibre diameter/cuticle scale length) increased as mean fibre diameter increased.

<p>| Table 2.1 Some attributes of cashmere samples from different regions processed by Erdos Cashmere Group during their survey work on cashmere properties. IM: Inner Mongolia |</p>
<table>
<thead>
<tr>
<th>Region</th>
<th>Clean washing yield (%w/w)</th>
<th>Mean fibre diameter (µm)</th>
<th>Dehaired fibre length (Barbe, mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ashlan League (IM)</td>
<td>47.2</td>
<td>14.1</td>
<td>42.2</td>
</tr>
<tr>
<td>Ali Area, Tibet</td>
<td>51.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Astad</td>
<td>54.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ba League, Wuzhong</td>
<td>52.4</td>
<td>15.3</td>
<td>35.5</td>
</tr>
<tr>
<td>Dandong, Liaoning Province</td>
<td>15.3</td>
<td>34.7</td>
<td></td>
</tr>
<tr>
<td>Eerduoosi (IM)</td>
<td>45.0, 51.2</td>
<td>14.8, 15.0</td>
<td>37.2, 42.0</td>
</tr>
<tr>
<td>Gaizhou Stud Farm</td>
<td>67.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gansu Province</td>
<td></td>
<td>13.8</td>
<td>37</td>
</tr>
<tr>
<td>Mongolian</td>
<td>57.6</td>
<td>16.9</td>
<td>37.8</td>
</tr>
<tr>
<td>Shangdong Province</td>
<td>50.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>You County</td>
<td>52.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Qinghai Province</td>
<td>54.8</td>
<td>14.6</td>
<td>27.7</td>
</tr>
<tr>
<td>Xing’an League (Xiwu)</td>
<td>45.8, 56.9</td>
<td>15.5, 15.5</td>
<td>36.2, 40.6</td>
</tr>
<tr>
<td>Xin Jiang Province</td>
<td>50.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Erdos scientists have closely studied the cashmere fibre morphology and classified cashmere fibre cuticle scales into three types of scale pattern: typical cylindrical patterns, irregular cylindrical patterns and variation patterns.

Based on the survey samples it was found that typically variation patterns accounted for about 1.4% by weight of the total (range 0.0 to 5.3%). The definitions of the three cuticle scale patterns are:

1. Typical cylindrical patterns. Even fibre diameter variation in axial direction, scales envelop fibre shaft flatly and regularly giving a smooth lustrous appearance. Scales regular and orderly. Scale frequency 57 to 64 per mm and scale height less than 0.4 µm.
2. Irregular cylindrical patterns. Morphology little different to typical cylindrical patterns but scale edge is not orderly with some high scale frequencies and larger scale heights.
3. Variation patterns. There are four types showing deviation from typical cylindrical patterns:
   - Low scale height and high scale frequency with scale edges bending outwards. Has appearance of fine sheep wool. Usually seen in 7 to 15 µm cashmere.
   - Low scale height and high scale frequency with scale edges exhibiting serrated appearance. Has appearance of goat guard hairs. Usually seen in 20 to 25 µm diameters.
   - Scales patterns are vague and scale edges come off in different extents. Similar to patterns of sheep wool after chemical treatment. Usually seen in 17.5 to 25.5 µm diameters.
   - Irregular scales with indistinct characteristics. Higher scale height and scale frequency with furrows on scale surface. Patterns and lustre resemble sheep wool. Usually seen in 17.5 to 25 µm diameters.

The initial definition of three fibre types may need revision. At the moment Erdos is circulating their research as a ‘draft’ national standard. Later, after further development, this work may be submitted for international acceptance. Based on their experience Erdos recommends the following:

1. Two years of training is generally required on animal fibre identification.
2. Frequent inter-laboratory comparison tests are required for accuracy.
3. Different parameters must be considered during comprehensive identification.
4. Comparisons should be made at a similar fibre diameter.
5. Variation cashmere is the most difficult to identify. Priority should be to identify mainly by scale morphology. Problems on the purity of cashmere samples only exist when variation cashmere content exceeds 5%. If the CVD of a sample exceeds 24% it is likely that the sample is blended with another fibre.
Photo 2.1. The scanning electron microscope used in the studies of cashmere and wool fibre cuticle morphology at the China National Engineering and Technology Research Centre for Cashmere Products, Erdos Cashmere Group Co. Ltd.

Professor Langley highlighted the difficulty in identifying Optim, steamed wool, dehaired yak wool and recycled cashmere when mixed with new cashmere. Interlaboratory round trials showed that quantifying yak in cashmere blends was a problem. Examining recycled cashmere for mechanical damage was necessary.

This paper describes a potentially faster and cheaper method of determining fibre scale frequencies. The method uses the single fibre analyser (SIFAN) to determine the along the fibre diameter profile. This information is then analysed by the Fast Fourier Transform technique using computer software. The paper shows the close association between the mean scale frequencies determined by this method and the traditional approach using SEM.

This paper proposes that instead of the expensive and difficult task of examining the morphology of fibre cuticle scales that an alternative approach of examining the internal morphology of cortical cells may be faster and cheaper. Preliminary data were presented and further work is required.

Fourier transform infrared microscope and differential scanning calorimeter have been used to analyse cashmere and wool. The results showed that both Chinese and Australian cashmere started absorbing heat at a relatively higher temperature but were thermally degraded quicker than other animal fibres tested. From the attenuated total reflectance spectra, the Chinese cashmere was clearly
different from Australian cashmere and wool. It may be possible to use this technique to differentiate animal fibres.

Gao, R. and Du, S. Study on the variation fibre pattern structure of cashmere and fine sheep wool. Proceedings 3rd International Cashmere Determination Technique Symposium: 235-241. These senior scientists from the Hebei Inspection and Quarantine Bureau and China Fibre Inspection Bureau provide further analyses of different samples of Chinese cashmere and Chinese wool from 6 and 8 provinces respectively. The content of variation fibres was observed as: cashmere 2 to 11% with a mean of 5.3% and: wool 5 to 19% with a mean value of 7.3%. They observed the cuticle scale frequency of typical cashmere as 61.7/mm (range 57 to 69/mm) and variation cashmere as 74.1/mm (range 72 to 81/mm). For the Chinese wool the observed the cuticle scale frequency of typical fine wool as 85/mm (range 73 to 90/mm) and variation fine wool as 61/mm (range 57 to 66/mm). These authors suggest that the stipulated allowance for the percentage of variation cashmere should be increased from 5 to 7%. There is little difference in fibre pattern structure between typical cashmere and variation fine wool and it is difficult to distinguish accurately. It is also impossible to separate ‘variation fine wool’ by dehairing technology from ‘normal typical wool’. Therefore it is impossible to blend cashmere with ‘variation fine wool’. They concluded that projection microscopes are not clear and precise enough to measure fibre scale frequency and that improved measuring equipment is needed. This paper caused long animated discussion based on the suggestion of increasing the allowable limit for variation fibre content.

2.1.2.2 Pilling in cashmere

Erdos scientists have taken the high ground by stating that the company is responsible for the quality of cashmere products. They want to reduce pilling for consumer satisfaction. They have found that the Random Tumble test is not satisfactory for cashmere as it cannot distinguish between lots. For a pilling test to be suitable, laboratory staff must be able to notice the effect of a test on the formation or loss of pills, especially hard pills. They have found that the ICI Pill Box Methods is more suitable. In Japan, the standard for cashmere knitwear is the ICI method with a duration of 5 hours. Similar findings about the suitability of the test method were made by McGregor in 2000 during his Ph.D. studies. This finding was not reported in detail in his thesis (McGregor 2001b) but an analysis was provided in a separate paper at this conference and is printed in full in Chapter 4.

Zhang, Z., Yang, G. and Meng, L. Determination of the pilling test time for cashmere knitwear. Proceedings 3rd International Cashmere Determination Technique Symposium: 68-80. These Erdos scientists provide a time/pill formation curve for cashmere. They demonstrate that using the ICI Pill Box Method that pills do not form in the initial 1-2 hours. The Erdos standards for the quality of cashmere knitwear state that the pilling and appearance change score should not be lower than 3.5 (out of 5 where no change occurs). Thus the testing time needed for different fabrics to reach a score of 3.5 was determined for cashmere fabrics. Not all cashmere fabrics exhibit pills even after extensive testing time. The appropriate testing time determined for woollen cashmere fabrics was 2 hours and 3 hours for worsted cashmere fabrics. Detailed photographs for pill formation in cashmere were provided for the first time. These photographs, if accepted as international standards will add to those provided for different types of wool.
2.1.2.3 Fibre length measurement

Fibre length affects the spinning performance of animal fibres and many yarn and fabric properties. Fibre length affects the price of processed cashmere. The traditional method of assessing the length of processed animal fibres in a processing works is to use a hand array length formally named a Baer Diagram. Over the past 40 years the Almeter, which measures fibre length indirectly by capacitance, has been the international standard for fibre length measurement. The Almeter estimates the Hauteur of tops or length after carding (LAC) as the mean length by number, Barbe (mean length by weight) and various other length measurements including the variability of measurements for suitably prepared samples.

Little has been published on the actual relationship between Baer Diagram midpoint length and Almeter measurements and no references could be found on this relationship with processed cashmere. During 1999, McGregor as part of his Ph.D. studies undertook a comparison of Baer Diagram and Almeter measurements. The findings were not reported in his thesis (McGregor 2001b) but the analysis was provided in a separate paper at this conference and is printed in full in Chapter 4. This analysis has been used to evaluate processed cashmere in the recent RIRDC Project DAV200A.


The author discusses the method of measuring fibre length by the two methods. No measurement data is provided and no statistical analyses are presented. The author concludes that:

- The hand array method required greater skill and has a low cost. Only a small sample is used that may not be representative. Practice improves accuracy.
- Almeter method is fast, can test more sample and there are less human errors but it can only operate on fully processed fibre. The equipment is expensive.
- The results of the two methods are very close to each other.
2.1.2.4 Cashmere marketing

Yan, L. How to avoid the disordered competition in China’s domestic cashmere market. Proceedings 3rd International Cashmere Determination Technique Symposium: 335-338.

The views of a Senior Textile Engineer from the Beijing Entry-Exit Inspection and Quarantine Bureau Technology Centre on cashmere marketing are interesting in the light of free enterprise development in China. She concludes that the present marketing conditions are disordered by multi-channel exporting, price competition among firms over the past 10 years and quality issues. She advocates that China establish a ‘Union of Cashmere Companies’ to reinforce self-discipline for the industry and to stipulate international standards for cashmere inspection.

There are four fundamental reasons for this proposal:

1. Low-level reconstruction resulted in redundant production capacity. Cashmere goat numbers increased from 17 to 60 million between 1980 and 2003 lifting raw cashmere production from 2800 to 9800 tonnes, 70% of the world supply. Processing capacity from 2600 firms now exceeds 20,000 tons of cashmere top, three times the world supply. The redundant capacity results in price escalation whenever cashmere is in short supply and firms cut prices whenever they have sufficient supply. Herdsmen are forced to slaughter goats leading to a malicious cycle between chains within the industry. Over the recent there have been four price wars, 1984, 1988, 1997, 2000, each time leading to many firms and herdsmen suffering a great loss while some brokers made a fortune.

2. Multi-channel exporting with price competition. China has no internationally known cashmere brand and less than 20% of cashmere products sold have a Chinese brand even though 75% of the cashmere comes from China. Most firms cannot manage intangible assets such as trade marks and patented technology. Thus firms depend upon commission agents for export leading to price competition for orders. Some loss selling occurs to obtain orders.

3. Substitution of fibres and inferior quality cashmere products. Mixing raw cashmere with other material for illegal gains occurs when cashmere prices rise. Long term harm has happened to the
Chinese cashmere industry with the supply of imitated or inferior quality cashmere products derailing the launching of brands on the international market.

4. Lack of industry cohesion and orderly competition. Some firms are speculating and driving prices higher when there are shortages and dumping product when prices are weak, thus exaggerating the price movements. The argument is put that the cashmere price should have a rational return to three sectors: herdsmen; semi-finished processing firms; and finished product processors. These problems are mainly within China yet the product is mainly an export product.

The author proposes these actions to keep the Chinese cashmere industry going on a healthy growth path by guaranteeing an orderly development of the market:

- Accelerate the process of cashmere industrialisation.
- Establish an authorised Union of Cashmere Companies to oversee self-management of the industry.
- The State establish a risk fund and interest-subsidy reserve system for regulating the supply and demand and market price for cashmere.
- Reinforce and stipulate international cashmere determination standards.
- Increase the policy support for the cashmere industry.

Photo 2.4. Textile scientists attending the Conference. From right to left:
Yan Lanzhen, Senior Textile Engineer from the Beijing Entry-Exit Inspection and Quarantine Bureau Technology Centre and author of paper on cashmere marketing;
Meng Linghong, Engineer Erdos Cashmere Group Ltd and Translator for conference;
Chen Jihong, Director China National Quality Supervision and Inspection Centre for Wool Textiles and Beijing Wool Textile Research Institute;
Zhang Meirong, Vice-Director Technological Centre of Erdos Cashmere Group Co. Ltd and China National Engineering and Technology Research Centre
2.2 China National Engineering and Technology Research Centre for Cashmere Products

The first National Centre for Textiles and the only one for cashmere was opened in 2002. The centre owns and manages:
1. Five internationally advanced pilot processing lines for animal fibre (stretching equipment, cashmere fancy yarns, knitting techniques, printing and dyeing on cashmere products, multi-blended worsted cashmere yarns).
2. Three standard testing laboratories.
3. Computer integrated scientific research system.

The standard laboratories are equipped with 42 sets of internationally advanced instruments. The laboratories are maintained in standard conditions through monitoring of the National Metrology Metering Station.

Imported machinery amounts to over 100 sets including German, Italian and French equipment.

The Centre aims to realise the sustainable development of the Chinese cashmere industry. The functions are:
1. Undertake National priority research.
2. Research and development on common key techniques and cross-techniques in textiles.
3. Industrialisation of the scientific finding in knowledge, information and new instruments.
4. Promote the capability of new innovations.
5. Lead technical innovation.

The Centre has 7 departments and a post-doctoral research station. The departments focus on new material development, new technology applications, inspection and testing, intellectual property, pilot plant management, standards research and apparel and style design. Staff include 22 senior scientists and 42 base grade scientists with 20 being externally funded.
2.2 Erdos Cashmere Group Co. Ltd.
2.2.1 Industrial Park Eerduosi City

Erdos was established in 1981 and now has 75 subsidiaries and 20,000 employees. Seventeen member companies process cashmere including 7 knitting, 3 spinning, 3 weaving. New companies have been established to introduce new technology in dyeing, spinning and knitting. Erdos Dong Xu Dyeing Co. Ltd has annual capacity of 1000 tonnes including special equipment for cone, hank, top and garment dyeing and automatic colour testing systems. Erdos Dong He Spinning Co. Ltd introduced Italian, German and Japanese woollen spinning facilities. Erdos cashmere is exported to 30 countries with 20 direct sales shops in Los Angeles, Tokyo, London, Moscow, Cologne, Hong Kong and Milan. Processing mills have been established in Mongolia. The National Technology centre for cashmere was opened at Erdos in 2001.

Equipment includes Octir cards, Bigagli spinning mules, Schlafhorst automatic winding, Murata twisting and Monteleone blending machines. Erdos Dong Li Knitting Co. Ltd was built in 2001 and in 2002 commissioned 96 Stool computer knitting machines from Germany. Dong Li can develop, design and produce 250,000 pieces of knitwear from 6.2 to 14 gauge. In total the Erdos Cashmere Group Industrial Park covers 72 square km and includes 91.4 square km of building area.

Annual sales exceed $AU700 million. The Erdos brand has been listed as one of the 20 most valuable brands in China, based on turnover, for six consecutive years. Cashmere production includes 5 million pieces of cashmere garments, 1200 tonnes of dehaired cashmere, 1,800 tonnes of cashmere yarns. The KVSS brand of dehaired cashmere is known as “Number 1 dehaired cashmere from China”. The brand is vertically integrated with more than 1000 sales centres in China including self-managing retail shops, co-operative shops and shopping centre sales halls. New products include “nano-metre” cashmere sweaters in 2002.

Quality assurance systems were introduced in 1995 following ISO9001 and ISO14000. In recent years Erdos cashmere products have also been approved as “international green textile products” by an ecological inspection association.

Photo 2.6. Dehairing of brown cashmere at a subsidiary of the Erdos Cashmere Group Co. Ltd
Photo 2.7. Top making of white cashmere at a subsidiary of the Erdos Cashmere Group

Photo 2.8. Processing of dyed dehaired cashmere on the woollen spinning system at a subsidiary of the Erdos Cashmere Group:
(a) woollen carding on Octir card;
(b) slub production on Octir card; and
(c) mule spinning of cashmere on Bigagli frame.
2.2.2 Rural supply networks

Erdos Cashmere Group has a supply chain consisting of networks of cashmere collection companies or associates that operate in cashmere producing regions. The Erdos collection company employs 600 people in 20 subsidiaries. In many cases the raw cashmere is being scoured and dehaired close to the collection area. Scoured dehaired cashmere is then transported to the Industrial Park for spinning and further processing.

In Wulan Town a scouring and dehairing operation was inspected. The scouring system was an older style 5 bowl scour. Following opening, bowl 1 rinsed the fibre, bowls 2 and 3 scoured, bowl 4 bleached the fibre and bowl 5 was rinsing. The cashmere was then dried and baled.

The dehairer was a typical flat cotton card. There were two separate lines each with four cards in line. The droppings from card 1 were processed through a 3 roller recovery dehairer and the product returned to the second dehairer in the main line. The atmosphere was humidified with pressurised water atomisers.
2.3 Inner Mogolia Arbls White Cashmere Goat Breeding Station

The station is situated 235 km west of Eerduosi City near National Freeway 109 and close to Wulan Town. The privately owned station claims to have the largest breeding herd in China. The station consists of four farms: breeding, propagating, forage grass supply and sperm freezing farms. These farms are from 5 to 70 km from Wulan Town. There are 166 staff including 22 professional and technical staff.

Livestock include: 12,000 Arbls white cashmere goats, 800 Kalakuer sheep, and 1000 Poll Dorset, Suffolk and German Mutton Merino. Each year sales include 7000 sheep, 200,000 AI straws, 5000 frozen embryos. Over 50,000 white cashmere goats have been sold to 13 provinces in China.

Scientific work on the station has been part of National and Province 5-year-plans to improve the cashmere goats and develop improved animal production and pasture management systems. Recently with the Agricultural University of Inner Mongolia, a project to study the molecular mechanisms in the heredity and genetic control of the white cashmere goats has begun. A BLUP animal model to assess the genetic progress of these goats has been instituted.

The Arbls White Cashmere goats are described as burly with strong bones, short of stature but solid of girth. The goats have good cashmere coverage, with clear fibre crimp, a lustrous appearance and a mean cashmere fibre diameter of approximately 14 µm. The combed fibre has a reported clean washing yield of 65%. At the time of the visit some areas of the fleece showed clear staple crimp, particularly on the neck of kids and bucks. The cashmere length was 2 to 3.5 cm. Reported dressing percentage at slaughter was 45 to 47%, kidding rate 160% but weaning rate 99%. Production is summarised in Table 2.2 Please note that the average fleece weight is the weight of combed fibre in
the greasy state. This fibre has a clean washing yield averaging 65% and contains hairs and skin pieces, although Erdos provided lower clean washing yield figures (Table 2.1).

Table 2.2. Average cashmere production of Arbls White Cashmere goats at the Breeding Station Wulan Town Inner Mongolia

<table>
<thead>
<tr>
<th>Age/Sex</th>
<th>Live weight (kg)</th>
<th>Average fleece weight (g)</th>
<th>Highest fleece weight (g)</th>
<th>Mean fibre diameter (µm)</th>
<th>Cashmere staple length (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bucks</td>
<td>62</td>
<td>925</td>
<td>1980</td>
<td>15.0</td>
<td>7.6</td>
</tr>
<tr>
<td>Does</td>
<td>43</td>
<td>700</td>
<td>1600</td>
<td>14.6</td>
<td>6.2</td>
</tr>
<tr>
<td>Hogget bucks</td>
<td>38</td>
<td>590</td>
<td>1090</td>
<td>13.0</td>
<td>5.6</td>
</tr>
<tr>
<td>Hogget does</td>
<td>27</td>
<td>620</td>
<td>1100</td>
<td>13.2</td>
<td>6.2</td>
</tr>
</tbody>
</table>

At the time of the visit adult does were two months pregnant and some recent abortions were apparent. The body condition score of bucks averaged 3.5 (medium to fat condition). For does the body condition scores averaged 2 to 2.3 (store to forward store). For hoggets the body condition score averaged 1.7 to 2.0 (backward to store condition). On the breeding farm the goats grazed the rangeland for most of the year. Coarse grasses and low browse plants provided the bulk of the herbage on offer. Soils were sandy or loess based, and the country was undulating. Ringlock 6 line fences with concrete posts were used throughout the property. No tall scrub or shelter was apparent. On the nearby propagating farm bucks were in feed lots. Their daily ration consisted of pasture hay and corn cobs. Silage was used in the winter period.

Within the breeding flock some animals showed signs of poor constitution with the following faults observed devils grip, hock and leg problems, depressed bridge of the nose. Most herds observed had 1 or 2 black or dark grey goats in amongst the white goats. I was informed that this was to bring good luck. It is likely that the “good luck” would follow heavy snowfalls when entrapped white goats become almost invisible but black goats would be more obvious to a shepherd in a ‘white-out’.

Photo 2.13. The author on the grasslands at Inner Mongolia Arbls White Cashmere Goat Breeding Station
Photo 2.14. Inner Mogolian Arbls White Cashmere Goats, top mature bucks, below, adult breeding does
Chapter 3 Benefits and significance

3.1 Benefits to grantee for his work

Benefits include the following:
1. Opportunity to publish cashmere research in the best international cashmere forum.
2. Networking with leading Chinese and International cashmere textile scientists with a good potential to establish further working contacts.
3. Update on developments in cashmere textile and measurement science.
4. Learning opportunity on new processing methods and equipment.
5. Market research into new cashmere products.
6. Production update from one of the leading cashmere studs in Inner Mongolia.

Erdos scientists acknowledged that their study of fibre surface properties was focussed on Chinese cashmere fibre and one wool sample from Australia. Verifiable and representative fibre samples from other (foreign) sources are needed for further progress. The Chinese research on fibre properties may be published in English provided specialist input can be obtained to ensure that the terms used are correct. Clearly there is further room to develop their current theories and definitions based on an expanded database. The initial definition of three fibre types may need revision. There was no evidence for discriminate analysis as used by the German scientists in the 1980s. There is also the problem of using bulk samples that may already be contaminated with wool fibre.

Three areas are identified as potential areas for collaboration.
1. Expanded study on cashmere and wool fibre surface properties.
2. Research into other attributes of cashmere fibre.
3. Research into the efficiency of cashmere dehairing and the quality of the dehaired product.

Based on a long involvement in cashmere, mohair and alpaca experimental research and the production of known samples from known treatments the author believes that it should be possible to make rapid advances in knowledge without having to repeat the initial collection and experimental phases of research. This data set already has the basic of completed fibre tests. Collaboration with Chinese scientists does offer hope for efficient and cost effective research. The priority for fundamental research into the fibre properties of cashmere, mohair and alpaca were highlighted in the RIRDC funded project ULA 8A, Properties and Performance of Goat Fibre - A review and interpretation of existing research results (Leeder et al. 1998).

3.2 Benefits for the Australian cashmere industry

Very efficient method of gaining access to new scientific information in a cost effective manner. Exposure of Australian science and technology to the Chinese cashmere industry.

3.3 Recommendations to RIRDC and the industry

The following activities are recommended:
1. Maintain awareness of future International Cashmere Determination Technique Symposia and make plans to attend.
2. Encourage submission of technical papers to future International Cashmere Determination Technique Symposia.
3. Develop opportunities for future research collaboration.
4. Consider hosting visits by Chinese scientists if they visit Australia for other functions such as IWTO meetings.
Chapter 4 Papers and references

4.1 Papers presented at conference

Four papers on cashmere research were presented by the author at the conference and are reproduced in full in the following pages. The papers were:


4.2 References


THE OBJECTIVE MEASUREMENT OF CASHMERE FIBRE CRIMP USING FIBRE CURVATURE

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Summary
Cashmere samples from China, Iran and Australia were measured for crimp frequency and fibre curvature. Fibre curvature measured with the OFDA100 optical scanner was highly correlated to hand measured cashmere fibre crimp frequency. Multiple regression analysis showed that cashmere fibre crimp frequency was best predicted by objective fibre curvature measurement. Fibre curvature was related to origin of cashmere, crimp frequency and mean fibre diameter. Objective fibre curvature measurement enables rapid measurement of a fundamental property of cashmere fibre, the fibre crimp frequency.

Introduction
Fibre curvature measurement (Swan 1994, Swan and Mahar 2000) enables an objective and fast method of measuring a fundamental property of Merino wool fibre, the fibre crimp frequency. Commercial measurement of fibre curvature is obtained with the Optical Fibre Diameter Analyser (OFDA) and Laserscan with strong agreement being obtained between these two instruments (Fish et al. 1999).

Fibre curvature (fibre crimp) relates to single fibres rather than to staple crimp. Cashmere fleeces generally do not show a clear staple crimp structure, as the fibres are not held in a state of strain within a staple. Compared with Merino fleece, the lack of staple crimp in cashmere may be due to: (i) a lower density of fibres; (ii) the presence of coarse guard hairs; (iii) the relative lack of wool wax; and/or (iv) the lack of adhesions between fibres within the fleece (McGregor 2001). Consequently, many observers have been led to the mistaken belief that cashmere fibre is not crimped. For example, the Technical Manager of Dawson International (Smith 1987) informed an international conference in Australia that “Cashmere is straight with no crimp, whereas wool is highly crimped. Cashmere has a wavy macro structure.” There are however Chinese cashmere goats that exhibit staple crimp (McGregor et al. 1991) where fibre adhesions are present (fibres were held in position by compacted scurf, dust and vegetable matter). As staple crimp is generally not present in cashmere fleeces, there are only two alternatives available for measuring the fibre crimp of cashmere fibres, either manually, which is time consuming, or by mechanised objective testing using modern fibre diameter measurement equipment to measure fibre curvature.

Until recently there was no objective information available on measurable fibre curvature attributes of cashmere. Following a survey of commercially dehaired cashmere, McGregor (2000, 2001) reported that cashmere from new production regions (Australia, New Zealand and USA) has significantly lower fibre curvature than cashmere from traditional sources such as Iran, Afghanistan, Mongolia and China.

No information has been found on typical or acceptable crimp frequencies, or of the relationship between fibre crimp frequency and objectively measured fibre curvature. This report provide information on the relationship between fibre crimp frequency and fibre curvature in cashmere.

Materials and Methods
Three sources of cashmere were examined:

1. Chinese Liaoning Cashmere. Mid-side samples were collected by cutting at the skin surface, at the end of the growing season from Liaoning cashmere goats at the Gai County Cashmere Goat Farm in Liaoning Province, Peoples Republic of China (McGregor et al. 1991).

2. Australian cashmere. Typical commercially shorn cashmere and extreme examples of Australian cashmere were sourced from the Australian Cashmere Marketing Corporation. From each commercial lot, a minimum of 16 random grab samples were taken. The extreme samples were very different in fibre crimp frequency, cashmere and guard hair fibre length and cashmere yield.

3. Iranian cashmere. Mid-side samples were collected by the author from the cashmere production areas of Baft and Birjand.

Fibre testing
The following tests were undertaken:
1. Mean fibre diameter, mean and variation and fibre curvature undertaken using the OFDA 100 following scouring in water and conditioning for 24 hours.

2. Fibre length. From each individual sample, three random staples were drawn. From each staple, the longest cashmere fibres were drawn. The fibres were gently drawn straight on a velvet board and measured to the nearest mm. The length obtained by this method is highly correlated \( r = 0.95 \) to WIRA single fibre length measurements (Teasdale et al. 1985).

3. Cashmere fibre crimp frequency (crimps/cm). Following the measurement of fibre length, other cashmere fibres were gently removed and allowed to relax on a velvet board. The board was placed on a dissecting microscope and the frequency of crimping was measured on at least 3 fibres per staple.

**Statistical analyses**

Data have also been analysed by linear and multiple regression analysis and lines of best fit are plotted with individual data (Genstat 2000). When the dependant variate was fibre curvature, no multiple regression contained two significant independent variates. The country of origin of the cashmere has been used within the variate Origin.

**Results**

The mean ± s.d. and range in crimp frequency was 3.6 ± 1.04, 1.5 to 7.0 crimps/cm; fibre curvature 54 ± 10.8, 27 to 84 degree/mm; cashmere length 72.3 ± 21.3, 32-134 mm; and mean fibre diameter 15.9 ± 1.99, 12.4 to 21.9 µm. Approximately 66% of fibres exhibited a crimp frequency between 3 and 4.6 crimps/cm. Cashmere from each origin had crimp frequencies below 3 and above 4.6 crimps/cm. The crimp frequency measurements are summarised in Figure 1.

The relationships between cashmere crimp frequency and fibre curvature, Origin of cashmere, cashmere length, mean fibre diameter and crimp frequency are given in Table 1.

**Discussion**

**Fibre crimp frequency**

Cashmere clearly exhibits single fibre crimp. The rate of cashmere fibre crimp frequency is associated with the origin of the cashmere, cashmere fibre length, cashmere mean fibre diameter and cashmere fibre curvature.

**Origin of cashmere**

Based on the samples measured, origin of cashmere explained about 10% of the variation in cashmere fibre crimp frequency. Chinese and Iranian cashmere had 0.7 to 0.8 more crimps per cm compared with Australian cashmere. The likely cause of this difference in crimp frequency is nutritional management McGregor (2003).

![Figure 1](image-url)
### Table 1. Regression constants, correlation coefficient and probability (P) for relationships between fibre crimp, fibre curvature and other attributes of raw cashmere

<table>
<thead>
<tr>
<th>Dependant variate</th>
<th>Fitted parameters</th>
<th>Estimate</th>
<th>se</th>
<th>RSD</th>
<th>R</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crimps/cm</td>
<td>Constant (Origin reference Australia)</td>
<td>3.15</td>
<td>0.17</td>
<td>0.99</td>
<td>0.32</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>Origin China</td>
<td>0.79</td>
<td>0.25</td>
<td></td>
<td></td>
<td>&lt; 0.005</td>
</tr>
<tr>
<td></td>
<td>Origin Iran</td>
<td>0.67</td>
<td>0.29</td>
<td></td>
<td></td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>Crimps/cm</td>
<td>Constant</td>
<td>4.47</td>
<td>0.41</td>
<td>1.02</td>
<td>0.23</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>Cashmere length</td>
<td>-0.0124</td>
<td>0.0054</td>
<td></td>
<td></td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>Crimps/cm</td>
<td>Constant</td>
<td>6.81</td>
<td>0.88</td>
<td>0.97</td>
<td>0.37</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>Mean fibre diameter</td>
<td>-0.203</td>
<td>0.055</td>
<td></td>
<td></td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Crimps/cm</td>
<td>Constant</td>
<td>0.133</td>
<td>0.448</td>
<td>0.79</td>
<td>0.66</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>Fibre curvature</td>
<td>0.0639</td>
<td>0.0082</td>
<td></td>
<td></td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Fibre curvature</td>
<td>Constant (Origin reference Australia)</td>
<td>69.2</td>
<td>11.1</td>
<td>6.58</td>
<td>0.79</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>Origin China</td>
<td>4.57</td>
<td>2.14</td>
<td></td>
<td></td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td></td>
<td>Origin Iran</td>
<td>12.1</td>
<td>2.17</td>
<td></td>
<td></td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>Crimps/cm</td>
<td>4.10</td>
<td>2.14</td>
<td></td>
<td></td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>Mean fibre diameter</td>
<td>-2.16</td>
<td>0.59</td>
<td></td>
<td></td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

**Cashmere length**

Increasing cashmere length was associated with a decline in crimp frequency. This observation supports the hypothesis suggested by McGregor (2003) that the rate of crimping of cashmere fibres is time dependent. Thus if fibres are longer then the rate of crimping will be reduced.
Mean fibre diameter
Based on the samples measured, mean fibre diameter explained about 14% of the variation in cashmere fibre crimp frequency. Over the normal range of cashmere mean fibre diameter (13 to 18 µm) the rate of fibre crimping is reduced by 1 crimp/cm. This reduction was measured in cashmere from all origins.

Fibre curvature
Based on the samples measured, fibre curvature explained about 44% of the variation in cashmere fibre crimp frequency. Cashmere fibre crimp rate increased by 1 crimp/cm for each 16 degrees/mm increase in fibre curvature. This rate of increase was measured in cashmere from all origins.

Fibre curvature
Over 60% of the variation in cashmere fibre curvature was explained by the origin of the cashmere, cashmere fibre crimp frequency and cashmere mean fibre diameter.

Origin of cashmere
Based on the samples measured, Iranian cashmere had 7 degrees/mm higher fibre curvature than Chinese Liaoning cashmere which had 5 degrees/mm higher fibre curvature than Australian cashmere. These findings with raw cashmere accord with the findings of McGregor (2000, 2001) in studies with processed dehaired cashmere and with cashmere tops (McGregor and Postle 2004).

Fibre crimp frequency
Increasing cashmere fibre crimp rate by 1 crimp/cm increased fibre curvature 4.1 degrees/mm. This rate of increase was in addition to effects of origin and mean fibre diameter.

Mean fibre diameter
Over the normal range of cashmere mean fibre diameter (13 to 18 µm) the rate of fibre curvature was reduced by 10.6 degrees/mm. This reduction was measured in cashmere from all origins and is in addition to the effects of origin and fibre crimp frequency.

Conclusion
Cashmere fibre crimp is strongly associated with objectively measured fibre curvature. Modern laboratory equipment now enables a rapid and reliable method of measuring a fundamental property of cashmere fibre, the frequency of fibre crimp via fibre curvature measurements.

Acknowledgments
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References
PILLING AND APPEARANCE CHANGE OF WORSTED SPUN CASHMERE KNITWEAR – A COMPARISON OF THE ICI PILLBOX AND THE RANDOM TUMBLE METHODS

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Summary
There were differences between the ICI Pill Box Method and the Random Tumble Method in the assessment of resistance to pilling and appearance change of worsted spun cashmere and cashmere superfine wool blend knit fabrics. The methods differed in both the significance and magnitude of responses and in the amount of fabric mass loss. Generally the addition of cashmere or of low crimp superfine wool resulted in fabrics being more resistance to pilling and appearance change compared with high crimp superfine wool and this was associated with increased fabric mass loss when assessed by the ICI Pill Box Method but not with the Random Tumble Method.

Introduction
Pilling is the progressive appearance, during use, of small balls of fibre on the surface of garments. Pilling occurs most rapidly where friction is greatest. Bending, torsion and rubbing cause fibres to migrate and then to entangle, sometimes with contaminants, and roll into balls secured to the fabric surface by several anchoring fibres. As there are lower cohesive forces in knitted fabric, as a result of lower twist in the yarn, fibre migration is easier than in worsted woven fabric. Practically all the fibres in pills are broken fibres and the mean diameter of fibres is finer than that of the fibres in the yarn as a whole. In wearer trials, pill weights produced in a given time may differ from person to person by a factor of three (Anon 1965, Stryckman 1972).

The high specific surface area of superfine (16.7 um) and ultrafine (14.5 um) wool, significantly increases the pilling and the felting propensities compared with coarser wool (Robinson 1998). Ultrafine wool fabrics will dry felt and this provides significant problems for knitwear. By treating superfine and ultrafine wool with synthetic polymers or chlorine to reduce felting, the handle of the wool is also reduced and the treated wool is perceived as being harsher than non-treated wool. Robinson reported that during wearer trials, consumers always preferred ultrafine wool to other wool products, but they were cautious about paying extra for the ultrafine wool.

Cashmere is often blended with superfine wool for worsted fabrics but with knitwear, cashmere is frequently used as pure cashmere. However cashmere knitwear is usually made from woollen spun yarns. Cashmere has different fibre surface properties compared with wool that may affect the propensity to pill when worsted spun with wool. There is no specific objective information available on the properties of cashmere and cashmere blends with wool on worsted spun knit fabric attributes.

The present work was part of a larger study and was undertaken to evaluate pilling and appearance change in cashmere and cashmere superfine wool blend worsted spun knit fabrics and the difference if any between test method.

Materials and Methods
The study was a replicated experiment: nine treatments each of three replicates. The design was: Blend / (WT * BR) x 3 replicates. Blend was analysed as: Control (CM), specified as 100% Australian cashmere; Blends, blends of cashmere with wool and the pure wool treatments. WT, wool type had two levels: SW, standard high crimp fine wool tops; LCW, soft handling low crimp fine wool tops. BR, referred to blend ratio and had four levels specified as: 75, 50, 25 and 0 referring to the percentage of cashmere in the blend. In the graphical presentation of results, BR 100 refers to the control, CM. Each replicate was a different tightness factor of plain knit fabric.

All fibre was processed into separate tops and following combing, but before gilling, was allocated at random into three replicates and treatments. Yarn (18 tex) was spun on a Zinser RM 421E1 spinning frame with a SKF drafting set and a 48 mm diameter ring using a twist factor of 3487 (822 tpm) to produce a strong yarn. Yarns were autoclaved after spinning and again after two folding the yarns. The autoclaved two folded yarns were waxed and wound. Knitted plain jersey fabrics were constructed on a circular 23 gauge knitting machine to three different tightness factors of 14.0, 15.5 and 17.0 tex ½/cm by altering the loop lengths. (These tightness factors equate to cover factors of 1.20, 1.32 and 1.45.) Fabrics were oven-dried and reconditioned.
The raw wool properties and those of the wool tops are described elsewhere (McGregor and Postle 2002). The mean fibre diameter of the greasy wool was 16.9 um and the cashmere 16.6 um. Low crimp wool had a lower fibre curvature; 74 vs 114 degree/mm (P<0.001); and a lower resistance to compression; 7.4 vs 10.4 kPa (P<0.001); than the standard high crimp wool. Cashmere had lower fibre curvature 48 degree/mm (P<0.001) and resistance to compression 3.7 kPa (P<0.001) than low crimp wool. The Hauteur of the pure tops was: cashmere 42.0; LCW 47.0; SW 50.5 mm with the Hauteur of blends declining linearly as cashmere content increased.

The following fabric tests were undertaken using Standard conditions where appropriate;
1. Resistance to pilling and change in fabric appearance (ICI Pill Box Method) using IWS TM 152 (IWS 1996b). The change in knitted fabric appearance was assessed using the standard SM 54 Botany wool photographs for knitted fabrics.
2. Pilling resistance using the random tumble method (ASTM D3512) was determined using a test period of 30 minutes.

An experienced independent observer was used to assess the fabrics after the test. Weight loss was determined by drying and reconditioning samples before and after the test using standard procedures. For the ICI Pill Box Method weight loss was only determined in pure wool and pure cashmere samples following a separate test cycle. Each method used three fabric samples.

Data were analysed using ANOVA analysis (Genstat Committee 2000). Results given in the text include the standard error of difference between means (sed). The subscript on the sed value indicates to which main effect comparison the value refers. Most results have been graphed. Plotted with the control treatment (pure cashmere) are error bars indicating the effective standard error (ese) for the comparison of any two means using the sed for the Blend.WT.BR interaction (Genstat 2000). The ese = sed/√2.

Results

ICI Pill Box Method
Compared with pure cashmere fabrics, fabrics made from Blends had significantly reduced resistance to pilling score (P<0.015). Wool type affected resistance to pilling score with LCW having higher resistance to pilling scores than SW (P<0.05). Increasing BR increased resistance to pilling score (P<0.001, Figure 1). A BR x WT interaction showed that there were different responses to BR with each WT (P<0.005). There were significant differences between wool types at BR0 and BR25 (P<0.05).

The main effects for wool type on the resistance to pilling and appearance change score were: CM 3.7, LCW 3.3, SW 3.0; sed_{CM-WT} 0.22; sed_{WT} 0.14.

Figure 1. The resistance to pilling and appearance change scores following testing using the ICI Pill Box Method or the Random Tumble Method of fabrics made from R36 tex/2 yarns of different superfine wool types and blend ratios with cashmere knitted into plain jersey fabrics. The higher the Score the greater the resistance to pilling and change in appearance.

Symbols: ■ Low crimp wool; ▲ Standard wool; ● pure Cashmere

The high resistance to pilling scores, indicating low incidence of pills, were associated with higher fabric weight loss (Table 1).

<table>
<thead>
<tr>
<th>Fabric</th>
<th>Mean weight loss (%) ± (SD)</th>
<th>Treatment Mean Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM</td>
<td>1.25 (0.28)</td>
<td>3.8</td>
</tr>
<tr>
<td>LCW</td>
<td>0.86 (0.19)</td>
<td>2.6</td>
</tr>
<tr>
<td>SW</td>
<td>0.67 (0.23)</td>
<td>1.9</td>
</tr>
<tr>
<td>sed; (Probability)</td>
<td>0.13; P = 0.01</td>
<td>0.29; P&lt;0.05</td>
</tr>
</tbody>
</table>

Table 1. The mean loss of mass during ICI Pill Box Method testing and the treatment mean resistance to pilling and appearance change score for knitted fabrics (tightness factor 15.5 tex^{1/2}/cm) made from 100% cashmere (CM), 100% low crimp wool (LCW) and 100% standard wool (SW)
Random Tumble Method
Compared with pure cashmere fabrics, fabrics made from Blends had significantly reduced resistance to pilling and appearance change score (P<0.05). Wool type affected resistance to pilling and appearance change score with LCW having higher scores than SW (P<0.015). Increasing BR increased resistance to pilling and appearance change score (P<0.005, Figure 1) with significant differences between wool types. A BR x WT interaction showed that there was no effect of BR with LCW but increasing BR with SW improved resistance to pilling and appearance change score (P<0.05). At BR0, SW had a significantly lower resistance to pilling and appearance change score than LCW(P<0.05). The main effects for wool type on the resistance to pilling and appearance change score were: CM 4.6, LCW 4.5, SW 4.3; sed_{CM,WT} 0.08; sed_{WT} 0.05.

There was no significant differences between Blends and wool types in fabric mass loss, CM 1.20, LCW 1.40, SW 1.36; sed_{CM,WT} 0.10; sed_{WT} 0.07; P<0.1. While BR significantly affected fabric mass loss, this occurred because BR75 fabrics lost more mass (1.63%) than both pure cashmere (1.20%) and other blends (1.30%) (sed_{CM,WT} 0.11; sed_{WT} 0.09; P<0.005).

Discussion
The ICI Pill Box and the Random Tumble methods differed in both the significance and magnitude of responses and in the loss of fabric mass. ICI Pill Box Method differentiated to a greater extent the effects of wool type and blend ratio of cashmere and wool compared with the Random Tumble Method.

In the present work, pure cashmere and low crimp wool were associated with significant improvement in resistance to pilling and appearance score when determined with the ICI Pill Box method. Increasing the content of cashmere improved resistance to pilling score. Using low crimp wool instead of standard high crimp wool also improved resistance to pilling and appearance change score.

Fibre type was associated with differential fibre loss in the ICI Pill Box Method indicating that the increasing resistance to pilling score as fibre type changed and/or blend ratio was increased was associated with loss of either the pills or fibre. These data therefore do not indicate the lack of pill formation per se.

The responses of pilling resistance to changes in fibre crimp measured in the present work and in unpublished data are greater than those detected by Hunter et al. (1981, 1982). In their work, resistance to pilling was mainly explained by variations in mean fibre diameter, with staple crimp explaining only 0.5% of the variation. These results may illustrate that in Hunter's wool there was strong co-linearity between mean fibre diameter and staple crimp.

Two other reports on resistance to pill formation and change in appearance of cashmere type fabrics have been found. Cowan (1989) reported that cashgora yarns following knitting did not pill and were seen to retain their handle after washing although no data was provided. Following 1000 cycles on the Martindale abrasion tester, Lam (1996) reported that fine cashmere (16 µm) and cashgora (20 µm) knitted fabric showed a better appearance with less pilling on the surface compared with wool (30 µm), mohair (22 µm) and alpaca/wool (25 µm) fabrics. Lam did not replicate the work and no data on fabric mass changes were provided.

The results of the present work are in general agreement with the theories of pill formation in wool fabrics (Anon 1965, Stryckman 1972) but there are some noticeable differences. For example:
1. for the same linear density of the yarn, pilling was greater for fabrics having fibres of longer, (as opposed to shorter) fibre length;
2. blends pilled less than pure wool component yarns rather than pilling more.

These differences to accepted pilling theory must be primarily related to differences in fundamental fibre properties, such as fibre curvature, between pure cashmere, low crimp wool and standard wool. In the present work, all other variables have been controlled to a high degree. It is also possible that some of the differences between the present work and accepted pilling theory (Anon 1965, Stryckman 1972) may be related to differences in the methods used for the measurement of pilling and change in appearance.

The present work has demonstrated that resistance to pilling in knit fabrics was crimp dependent and further analyses of the full set of fabrics with differing loop lengths is being undertaken.

Conclusion
There were differences between methods in the assessment of resistance to pilling and appearance change in worsted spun cashmere and cashmere wool blend knit fabrics. Generally the addition of cashmere or of low crimp superfine wool resulted in fabrics
being more resistance to pilling and appearance change compared with high crimp superfine wool and this was associated with increased fabric mass loss when assessed by the ICI Pill Box Method.

References
MEASURING PROCESSED CASHMERE LENGTH AND DIAMETER WITH THE OFDA4000 AND THE RELATIONSHIP TO MEASUREMENT OF LENGTH BY ALMETER

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Summary

The OFDA4000 was used to measure the fibre length, Hauteur, length distribution attributes and mean fibre diameter in cashmere tops and slivers. Length measurements were compared with Almeter determinations of the same length attributes. The OFDA4000 proved to be a rapid and direct method of measuring cashmere fibre length in tops and slivers. There were differences between the Almeter and the OFDA4000 measurement of Hauteur, fibre distribution and length measurements that may be associated with differences in the measurement of short and long fibres and in changes in mean fibre diameter along the fibre. The OFDA4000 along fibre profile indicated an increase in fibre cross-section area of 27 to 30% from the beard end. The OFDA4000 proved to be a rapid and direct method of measuring cashmere fibre length in tops and slivers.

Introduction

Over the past 40 years the Almeter, which measures fibre length indirectly by capacitance, has been the international standard for fibre length measurement (IWTO-17 1967) in tops and slivers. The Almeter scans a prepared fibre array with a capacitance sensor to estimate the quantity of fibre at each point along the fibre array. The Almeter estimates the Hauteur of tops or length after carding (LAC) as the mean length by number, Barbe (mean length by weight) and various other length measurements including the variability of length measurements for suitably prepared samples.

According to the operating manual for the Almeter (Anon 1980) there are three main fibre states; fully relaxed and crimped, semi-rectified and fully rectified or uncrimped. In the semi-rectified state only a reduced amount of fibre crimp remains. This fibre state can be described as “partially crimped”. The semi-rectified state can be considered as a stable state from top to roving, as further gilling in preparation for spinning only very slightly improves the rectification of the fibres (Anon 1980). The Almeter measures the fibres in this partially crimped state, that is the state of fibres in various phases such as top drawn slivers, roving and yarn as well as in the machines. The fully rectified or uncrimped state does not correspond to any states occurring in practical operations as in all finished and seminished textiles individual fibres are in a partially relaxed state. In processing machines fibres are tensioned in large groups not individually (Anon 1980).

Length can be based on three different measurements (Anon 1980):

1. Mean length based on fibre count (L, unbiased): 
   \[ L = \frac{\sum l_i}{n} \]

2. Mean length based on fibre cross-section (Hauteur, H, cross-section biased mean length): 
   Mean Hauteur is defined by: 
   \[ H = \frac{\sum a_i l_i}{\sum a_i} \]

3. Mean length based on fibre weight (Barbe, B, weight-biased mean length): 
   \[ B = \frac{\sum w_i l_i}{\sum w_i} \]
   where: \( w \) (weight) = \( a \ l \ \delta \) (cross-section area x length x specific density).
   If the specific density of fibres is constant then: 
   \[ B = \frac{\sum a_i l_i^2}{\sum a_i l_i} \]
   If all fibres have the same cross-section area: 
   \[ B = \frac{\sum l_i^2}{\sum l_i} \]

The Almeter assumes that with normal processing lots of wool the percentage of fibres biased by cross-section area are approximately equivalent to the percentage of fibres by number. With Hauteur diagrams all fibres have the same importance with respect to their percentage in cross-section, long or short but in Barbe diagrams the longer fibres have greater importance. However with blends of lots with large differences in mean diameter and mean length, large differences are seen between cumulative, numerical and cross-section biased diagrams (Anon 1980).

The Almeter is an expensive piece of equipment and preparation of samples using the separate Fibroliner is time consuming and therefore costly. In some processing facilities Baer Diagram fibre length arrays are used to estimate fibre length (Onions 1962). In textile laboratories separate equipment is also required to measure mean fibre diameter.
According to Brims (2002, 2004) and Anon (2005) the recently developed OFDA4000 incorporates features of the laboratory based OFDA100 with the along-the-fibre measurement features of the OFDA2000 adapted to measure processed fibres. It is claimed that the OFDA4000 provides the following benefits:

- Uses a smaller and integrated fibre aligner compared with the Almeter Fibroliner;
- Less instruments and computers providing a lower total cost compared with ownership of the 3 instruments it replaces (Fibroliner, Almeter, OFDA100 or Laserscan);
- Labor cost savings due to one sample preparation and no operator involvement in measurement phase;
- Measures the actual length and diameter as well as Hauteur and Barbe simultaneously;
- Determines automatically for the first time fibre diameter vs. fibre length profiles;
- Can measure all animal and other fibres for diameter and fibre curvature attributes;
- Measures diameter of cut fibres in glass slides (emulates OFDA100) for non-aligned fibres;
- Blends of different fibres can be measured accurately, which is not possible using capacitance based instruments.

As the measurement of processed cashmere fibre length is notoriously difficult, in part owing to the large number of short fibres, this paper reports an investigation into the feasibility of measuring cashmere tops and dehaired cashmere slivers on the OFDA4000 and the relationships between OFDA4000 and Almeter measurements.

**Materials and Methods**

Cashmere tops (n = 12) and dehaired cashmere (n = 16) were selected from a larger collection to cover the range in known Hauteur, measured mean fibre diameter and countries of origin. Countries of cashmere origin were China, Iran, Afghanistan, Mongolia, Turkey and Australia. Additional samples (n = 3) of dehaired llama from Bolivia, Yak wool from China and Baby camel from Mongolia were also tested. The dehaired cashmere, llama, yak wool and camel were converted into slivers using a modified length after carding procedure (McGregor 2001, McGregor 2005), twist was applied and slivers stored. Fibre length was measured on the Almeter (IWTO-17 1967) although three tops did not have independent Almeter tests. Mean fibre diameter (MFD) and variation and fibre curvature were measured following aqueous scouring and conditioning for 24 hours. Two sub-samples were measured twice (8000 counts each measurement) using the OFDA100 (IWTO 1995). Both tops and slivers were then measured on the OFDA4000 (Brims 2002, 2003, 2004) for MFD, fibre length, Hauteur and associated length attributes. The MFD of the fibre ends (at the beginning of each beard) and the change in MFD along the fibre from the beard end were determined. Each sample was measured twice (minimum count 8000 fibres per replicate) following a pre-draw of 100 mm and a measurement interval of 5 mm.

The change in fibre cross section area was calculated from the fibre diameter fibre length profile as: \((\text{MFD at fibre end} + \text{increase in MFD along fibre})^2 / \text{MFD at fibre end}\)². The difference between OFDA4000 and Almeter measurements and the average of OFDA4000 and Almeter measurements of the same attribute were calculated. Means of replicate measurements were analysed by regression analysis (Genstat Committee 2000) and graphs were prepared. As three non-cashmere slivers formed part of the cashmere population and were not identified as outliers they have not been separately identified in the results.

**Results**

Mean, minimum, maximum and standard deviation (SD) of data for cashmere tops and cashmere slivers are provided in Table 1. An operator view of the OFDA4000 and of the computer screen are shown in Photo 1.

![Photo 1](image-url)
Table 1. The mean, SD and range in attribute values for fibre diameter and fibre length determined by the OFDA100, OFDA4000 and Almeter on cashmere tops and dehaired slivers

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Cashmere tops</th>
<th>Cashmere slivers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Minimum</td>
</tr>
<tr>
<td><strong>OFDA100 measurements</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean fibre diameter µm</td>
<td>17.3</td>
<td>15.2</td>
</tr>
<tr>
<td>Fibre curvature deg/mm</td>
<td>58.2</td>
<td>50.2</td>
</tr>
<tr>
<td><strong>OFDA4000 measurements</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean fibre diameter µm</td>
<td>17.2</td>
<td>15.3</td>
</tr>
<tr>
<td>Fibre end diameter µm</td>
<td>16.5</td>
<td>14.7</td>
</tr>
<tr>
<td>Increase in mean diameter along the fibres um</td>
<td>2.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Change in cross-section area along the fibres %</td>
<td>+27.5</td>
<td>+16.8</td>
</tr>
<tr>
<td>Mean fibre length mm</td>
<td>36.0</td>
<td>27.4</td>
</tr>
<tr>
<td>CV length %</td>
<td>45.3</td>
<td>32.3</td>
</tr>
<tr>
<td>% fibres &lt; 10 mm</td>
<td>80.2</td>
<td>64.8</td>
</tr>
<tr>
<td>Longest 1% fibres mm</td>
<td>77.9</td>
<td>66.9</td>
</tr>
<tr>
<td>Hauteur mm</td>
<td>39.7</td>
<td>31.5</td>
</tr>
<tr>
<td>CVH %</td>
<td>43.1</td>
<td>33.6</td>
</tr>
<tr>
<td>H% fibres &lt;10 mm</td>
<td>74.9</td>
<td>59.2</td>
</tr>
<tr>
<td>HL1% mm</td>
<td>86.8</td>
<td>75.4</td>
</tr>
<tr>
<td>Barbe mm</td>
<td>47.1</td>
<td>38.8</td>
</tr>
<tr>
<td><strong>Almeter measurements</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hauteur mm</td>
<td>39.5</td>
<td>32.5</td>
</tr>
<tr>
<td>CVH %</td>
<td>42.3</td>
<td>31.8</td>
</tr>
<tr>
<td>H% fibres &lt;10 mm</td>
<td>1.0</td>
<td>0.0</td>
</tr>
<tr>
<td>HL1% mm</td>
<td>86.6</td>
<td>75.4</td>
</tr>
<tr>
<td>Barbe mm</td>
<td>46.7</td>
<td>39.7</td>
</tr>
</tbody>
</table>
Figure 1. The relationship between OFDA4000 measurements of cashmere fibre length and Almeter estimations. Symbols: Cashmere tops ▲; Cashmere length after carding slivers ●

Figure 2. The relationship between OFDA4000 measurements of cashmere fibre length and Almeter estimations. Symbols: Cashmere tops ▲; Cashmere length after carding slivers ●
Table 2. Regression and correlation coefficients and the statistical significance for the relationships between OFDA4000 Almeter measurements (shown by subscript \text{OFDA}) and Almeter estimates of Hauteur (H), CVH, Barbe (B), \% of fibres < 10 mm (H<10), length of longest 1% of fibres (HL1) and the OFDA4000 measurements of unbiased fibre length (LOFDA), CVlength, \% of fibres < 10 mm (L<10\text{OFDA}) and length of the longest 1% of fibres (L1\text{OFDA}). Diff is difference between measurement methods of the same attribute regressed against the average of the means.

<table>
<thead>
<tr>
<th>Response variate</th>
<th>Regression constant</th>
<th>Dependent variate</th>
<th>Regression coefficient (se)</th>
<th>r</th>
<th>RSD</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cashmere tops (n = 9 or 12)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LODFA</td>
<td>-3.92</td>
<td>H\text{OFDA}</td>
<td>1.006 (0.0799)</td>
<td>0.97</td>
<td>1.00</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LODFA</td>
<td>-2.35</td>
<td>H</td>
<td>0.936 (0.150)</td>
<td>0.91</td>
<td>1.40</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LODFA</td>
<td>-6.80</td>
<td>Average H</td>
<td>1.07 (0.121)</td>
<td>0.95</td>
<td>1.03</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>H\text{OFDA}</td>
<td>6.82</td>
<td>H</td>
<td>0.80 (0.129)</td>
<td>0.91</td>
<td>1.21</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Diff H</td>
<td>4.57</td>
<td>Average H</td>
<td>-0.15 (0.155)</td>
<td>0</td>
<td>1.31</td>
<td>NS</td>
</tr>
<tr>
<td>B\text{OFDA}</td>
<td>-0.57</td>
<td>B</td>
<td>0.99 (0.104)</td>
<td>0.96</td>
<td>0.92</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Diff B</td>
<td>-2.30</td>
<td>Average B</td>
<td>0.03 (0.103)</td>
<td>0</td>
<td>0.91</td>
<td>NS</td>
</tr>
<tr>
<td>CVLength</td>
<td>-3.34</td>
<td>CVH\text{OFDA}</td>
<td>1.13 (0.122)</td>
<td>0.94</td>
<td>2.23</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CVLength</td>
<td>6.75</td>
<td>CVH</td>
<td>0.92 (0.144)</td>
<td>0.91</td>
<td>3.13</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CVH\text{OFDA}</td>
<td>10.08</td>
<td>CVH</td>
<td>0.795 (0.0708)</td>
<td>0.97</td>
<td>1.54</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Diff CVH</td>
<td>10.20</td>
<td>Average CVH</td>
<td>-0.204 (0.0870)</td>
<td>0.60</td>
<td>1.71</td>
<td>0.051</td>
</tr>
<tr>
<td>L&lt;10\text{OFDA}</td>
<td>5.20</td>
<td>H&lt;10\text{OFDA}</td>
<td>1.002 (0.0304)</td>
<td>0.99</td>
<td>0.73</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>L&lt;10\text{OFDA}</td>
<td>83.08</td>
<td>H&lt;10</td>
<td>0.29 (1.08)</td>
<td>0</td>
<td>4.40</td>
<td>NS</td>
</tr>
<tr>
<td>L1\text{OFDA}</td>
<td>11.24</td>
<td>HL1</td>
<td>0.751 (0.0482)</td>
<td>0.98</td>
<td>1.17</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Diff (L1\text{OFDA}-HL1)</td>
<td>11.85</td>
<td>Average (L1\text{OFDA}+HL1)/2</td>
<td>-0.272 (0.0625)</td>
<td>0.83</td>
<td>1.33</td>
<td>0.003</td>
</tr>
<tr>
<td><strong>Cashmere slivers (n = 16)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LODFA</td>
<td>-2.53</td>
<td>H\text{OFDA}</td>
<td>0.917 (0.0236)</td>
<td>0.99</td>
<td>0.59</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LODFA</td>
<td>5.29</td>
<td>H</td>
<td>0.807 (0.113)</td>
<td>0.88</td>
<td>2.87</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LODFA</td>
<td>0.20</td>
<td>Average H</td>
<td>0.907 (0.066)</td>
<td>0.96</td>
<td>1.63</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>H\text{OFDA}</td>
<td>8.27</td>
<td>H</td>
<td>0.889 (0.115)</td>
<td>0.89</td>
<td>2.93</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Diff H</td>
<td>5.65</td>
<td>Average H</td>
<td>-0.012 (0.123)</td>
<td>0</td>
<td>3.03</td>
<td>NS</td>
</tr>
<tr>
<td>B\text{OFDA}</td>
<td>9.18</td>
<td>B</td>
<td>0.848 (0.0971)</td>
<td>0.91</td>
<td>3.66</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Diff B</td>
<td>6.66</td>
<td>Average B</td>
<td>-0.084 (0.110)</td>
<td>0</td>
<td>3.89</td>
<td>NS</td>
</tr>
<tr>
<td>CVLength</td>
<td>-0.04</td>
<td>CVH\text{OFDA}</td>
<td>1.104 (0.0800)</td>
<td>0.96</td>
<td>1.10</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CVLength</td>
<td>27.6</td>
<td>CVH</td>
<td>0.50 (0.263)</td>
<td>0.38</td>
<td>3.76</td>
<td>0.079</td>
</tr>
<tr>
<td>CVH\text{OFDA}</td>
<td>19.5</td>
<td>CVH</td>
<td>0.535 (0.215)</td>
<td>0.51</td>
<td>3.07</td>
<td>0.026</td>
</tr>
<tr>
<td>Diff CVH</td>
<td>-8.9</td>
<td>Average CVH</td>
<td>-0.044 (0.286)</td>
<td>0</td>
<td>3.54</td>
<td>NS</td>
</tr>
<tr>
<td>L&lt;10\text{OFDA}</td>
<td>15.33</td>
<td>H&lt;10\text{OFDA}</td>
<td>0.884 (0.026)</td>
<td>0.99</td>
<td>1.04</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>L&lt;10\text{OFDA}</td>
<td>66.86</td>
<td>H&lt;10</td>
<td>0.972 (0.352)</td>
<td>0.55</td>
<td>7.65</td>
<td>0.015</td>
</tr>
<tr>
<td>L1\text{OFDA}</td>
<td>15.88</td>
<td>HL1</td>
<td>0.749 (0.0865)</td>
<td>0.91</td>
<td>6.38</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Diff (L1\text{OFDA}-HL1)</td>
<td>12.49</td>
<td>Average (L1\text{OFDA}+HL1)/2</td>
<td>-0.211 (0.109)</td>
<td>0.39</td>
<td>7.18</td>
<td>0.074</td>
</tr>
</tbody>
</table>
The relationships between OFDA4000 fibre length measurements and Almeter estimates of fibre length are shown in Figures 1 and 2. Regression and correlation coefficients for these relationships are shown in Table 2. Examples of OFDA4000 fibre diameter profiles along the fibre are given in Figure 3.

**Discussion**

The cashmere samples tested covered the typical commercial range of cashmere fibre diameter (14.1 to 21.0 µm) and cashmere fibre length (Hauteur 15 to 44 mm, Table 1).

There was good agreement between OFDA4000 fibre length and OFDA Hauteur but poorer agreement between OFDA4000 mean fibre length and Almeter Hauteur (Table 2 and Figure 1). The differences between the two measurement methods was greater in cashmere slivers than with cashmere tops. The differences in Hauteur for slivers was constant over the range of Hauteurs measured (Figure 1) while for tops the differences were clustered around zero. This indicates that the software in the OFDA4000 can reliably emulate the Almeter estimations of Hauteur in tops.

OFDA4000 CVlength was closely associated with OFDA4000 CVH for tops and slivers. OFDA4000 CVlength was closely associated with Almeter CVH for tops but there was no significant association between OFDA4000 CVlength and Almeter CVH for slivers (Table 2). There were very high correlations between OFDA4000 measurement of the percentage of fibres shorter than 10 mm (L<10) and the OFDA4000 Almeter H%<10 mm (Figure 2, Table 1) for tops and slivers, however there was no correlation for L<10 and the Almeter equivalent H%<10 mm for tops (Figure 2, Table 1).

For the longest 1% of fibres there were large differences between the methods as shown by regression coefficients and the differences increased as the length of the longest 1% of fibres (L1) increased (Figure 2, Table 1).

The along fibre profiles of mean fibre diameter show that in all samples the mean fibre diameter increased from the beard end, with an average increase of 2.3 um (Table 1, Figure 3). These increases equate to an average increase in fibre cross-section area of 27 to 30% (Table 1). This indicates that the statement by the makers of the Almeter that “with normal processing lots of wool the percentage of fibres biased by cross-section area are approximately equivalent to the percentage of fibres by number” (Anon 1960) was incorrect for these cashmere tops and cashmere slivers.

For tops, the poor relationships between many Almeter Hauteur and OFDA4000 Hauteur measurements compared with the relationships between OFDA4000 fibre length and OFDA4000 Hauteur measurements may be explained by the differences between the measurement methods in the estimates of the length of the longest 1% of fibres and the incidence of the short fibres (< 10 mm). These inconsistencies may be related to the effects of the large increase in fibre cross-section area as fibre length increased.

Brims (2003) reported that Hauteur measured on 43 wool tops by Almeter was poorly correlated to mean fibre length measured by OFDA4000 and there was a poor relationship between short fibre content (% fibres < 25 mm) estimated by both methods. He concluded that Almeter underestimates short fibres by a large magnitude, a finding similar to that in the present work with cashmere. The Almeter is different to the OFDA4000 and this could be due to beard alignment, capacitance effects and diameter cross-section profile.

In undertaking these measurements the OFDA Fibroliner4000 significantly reduced labour compared with the operation of the Almeter. This allowed the author to complete other tasks while the automatic operation and adjustments built into the software enabled the Fibroliner4000 to efficiently process double layers of cashmere slivers or cashmere tops. The direct measurement of the length of 16000 fibres in 15 to 20 minutes by the OFDA4000 was an undertaking that would not have been considered possible with existing resources.
Conclusion
The OFDA4000 proved to be a rapid and direct method of measuring cashmere fibre length in tops and slivers. There were differences between the Almeter and the OFDA4000 measurement of Hauteur and fibre distribution and length measurements that may be associated with differences in the measurement of short and long fibres and in changes in mean fibre diameter along the fibre.

Acknowledgments
Mr. Mark Brims, BSC Electronics for access to the OFDA4000.

References
Anonymous (1980). Operating Instructions, texLAB AL 100 fiber length measuring instrument (Almeter). (Siegfried Peyer AG, Switzerland).
RELATIONSHIP BETWEEN BAER DIAGRAM HAND ARRAY LENGTH AND ALMETER LENGTH MEASUREMENTS FOR DEHAIRRED CASHMERE

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Summary
Dehaired cashmere tested using the length after carding procedure indicated that there was a useful relationship between Baer Diagram hand array and a range of Almeter length measurements. The Baer Diagram hand array midpoint length explained 77% of the variation in cashmere length after carding (LAC). The regression equation indicated a slope no different from one and a regression constant of –11. In other words, to estimate LAC, 11 mm should be taken from the Baer Diagram midpoint length determination. The addition of other objective measurements such as mean fibre diameter or fibre curvature did not improve the predictive value of the relationships.

Introduction
Fibre length affects the spinning performance of animal fibres and many yarn and fabric properties (Hunter 1980, 1993). Fibre length affects the price of processed cashmere. The traditional method of assessing the length of processed animal fibres in a processing works is to use a hand array length or hand array length formally named a Baer Diagram (Onions 1962). Over the past 40 years the Almeter, which measures fibre length indirectly by capacitance, has been the international standard for fibre length measurement (IWTO-17 1967). The Almeter estimates the Hauteur of tops or length after carding (LAC) as the mean length by number, Barbe (mean length by weight) and various other length measurements including the variability of measurements for suitably prepared samples.

The Almeter is an expensive piece of equipment and preparation of samples is time consuming and therefore costly. Using the Almeter induces a delay in fibre measurement if the results are required for quality control purposes during processing, machinery set-up and monitoring when results are required immediately. As many processing works do not have Almeters on hand Baer Diagrams are used for monitoring product length. The commonly quoted Baer Diagram hand array fibre length value is the midpoint length, although the maximum, 95% of maximum, 5% of maximum and minimum are often determined, particularly during top making. Processed animal fibres are sold on the basis of Baer Diagram midpoint length, presumably being regarded as an estimate of Hauteur or LAC. For dehaired cashmere the midpoint length is an estimate of the length after carding.

Little has been published on the actual relationship between Baer Diagram midpoint length and Almeter measurements and no references could be found on this relationship with processed cashmere. This paper reports an investigation into the relationships between Baer Diagram measurements and Almeter measurements using dehaired cashmere.

Materials and Methods
Samples of dehaired cashmere (n = 14) were selected from a larger collection to cover the range in known cashmere length after carding, measured mean fibre diameter and countries of origin. Countries of cashmere origin were China, Iran, Afghanistan, Turkey, Mongolia, Australia and USA. Prior to assessment, the dehaired cashmere samples were processed using a modified length after carding procedure (McGregor 2001). This procedure generally follows NZS 8719 (1992) and Mahar et al. (1996). Prior to measurement on the Almeter (IWTO-17 1967), 2 layers of sliver were laid onto the Fibroliner and the first 50 draws were discarded. The next 4 successive beards produced, each consisting of 12 to 15 draws, were measured. This process was repeated for 3 hanks for each sample and the mean lengths determined. Further hanks were available for the independent assessment of Baer Diagram hand array length by a very experienced Process Director from a leading cashmere dehairing company. Samples were presented in a randomised fashion with no information provided and identified only by a number. For each sample, five separate measurements were made and the means determined. Mean fibre diameter and variation and fibre curvature were measured following aqueous scouring and conditioning for 24 hours. Two sub-sample were measured twice (8000 counts each measurement) using the OFDA 100 (IWTO-47 1995). Data were analysed by linear and multiple regression analysis (Genstat 2000). A new variate was calculated as the average of the (95% of the maximum and 5% of the maximum Baer Diagram hand array length).
Results

Mean fibre length test data is provided in Table 1. The mean (± SD) and range of fibre diameter and fibre curvature was: 16.9 (2.0), 14.1-21.0 µm; 56.4 (10.8), 29-71 degree/mm.

The relationship between length after carding (LAC) and Baer Diagram mid point length is shown in Figure 1. Regression and correlation coefficients for the relationships between the various measurements are shown in Table 2.

Table 1. The mean, SD and range in attribute values for length after carding (LAC), LAC Barbe (B), Almeter measurements and Baer Diagram hand array lengths (all lengths in mm)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>LAC Mean</th>
<th>LAC Minimum</th>
<th>LAC Maximum</th>
<th>LAC SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>%&lt;10</td>
<td>27.2</td>
<td>15.0</td>
<td>44.0</td>
<td>8.4</td>
</tr>
<tr>
<td>HL5%</td>
<td>23.8</td>
<td>12.7</td>
<td>41.0</td>
<td>8.7</td>
</tr>
<tr>
<td>HL1%</td>
<td>61.9</td>
<td>34.5</td>
<td>101.8</td>
<td>18.0</td>
</tr>
<tr>
<td>“B”</td>
<td>77.0</td>
<td>44.8</td>
<td>133.9</td>
<td>22.8</td>
</tr>
<tr>
<td>LAC“B”</td>
<td>39.2</td>
<td>20.8</td>
<td>65.2</td>
<td>12.1</td>
</tr>
<tr>
<td>%&lt;10</td>
<td>7.7</td>
<td>2.4</td>
<td>20.0</td>
<td>5.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mid length</th>
<th>Max length</th>
<th>95% of max length</th>
<th>5% of max length</th>
<th>Average 95% &amp; 5% length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>38.1</td>
<td>98.8</td>
<td>75.5</td>
<td>15.7</td>
<td>45.6</td>
</tr>
<tr>
<td>Minimum</td>
<td>28.0</td>
<td>60.0</td>
<td>53.0</td>
<td>13.0</td>
<td>33.0</td>
</tr>
<tr>
<td>Maximum</td>
<td>50.0</td>
<td>150.0</td>
<td>95.0</td>
<td>22.0</td>
<td>56.5</td>
</tr>
<tr>
<td>SD</td>
<td>7.5</td>
<td>23.4</td>
<td>14.2</td>
<td>2.8</td>
<td>8.2</td>
</tr>
</tbody>
</table>

Discussion

The Baer Diagram hand array midpoint length explained 77% of the variation in cashmere length after carding (LAC). The regression equation indicated a slope no different from one and a regression constant of –11. In other words, to estimate LAC, 11 mm should be taken from the Baer Diagram midpoint length determination.

The relation between the LAC determination of “Barbe” or length by weight, and the Baer Diagram midpoint length explained 79% of the variation. The regression equation indicated a slope no different from 1.5 and a regression constant of –16. In other words, to estimate the LAC “Barbe”, the Baer Diagram midpoint length should be multiplied by 1.5 and that value should then be reduced by 16 mm.

Baer Diagram midpoint length was correlated with fibre diameter and fibre curvature (r = 0.44 to 0.53) and they respectively accounted for 20% and 28% of the variation in midpoint length. However, the addition of objective measurements such as mean fibre diameter or fibre curvature did not improve the predictive value of the relationship between Baer Diagram midpoint length and LAC or midpoint length and “Barbe”. Using the average of Baer Diagram (95% and 5% of maximum length) slightly improved the prediction of LAC. Relationships between other attributes measured by the two techniques showed correlations similar to that detected between LAC and Baer Diagram midpoint length.
Table 2. Regression and correlation coefficients and the statistical significance for the relationships between cashmere sliver Baer Diagram hand array measurements (BD) and the Almeter measurements of length after carding (LAC) and “Barbe” (LACB), % of fibres < 10 mm (L<10), length of longest 5% (HL5) and 1% of fibres (HL1). (BD midpoint length (BDML), 95% (BD95) and 5% (BD5) of maximum (max) length, n = 14)

<table>
<thead>
<tr>
<th>Response variate</th>
<th>Regression constant</th>
<th>Dependent variate</th>
<th>Regression coefficient (se)</th>
<th>r</th>
<th>RSD</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAC</td>
<td>-11.1</td>
<td>BDML&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.01 (0.15)</td>
<td>0.88</td>
<td>3.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LACB</td>
<td>-16.3</td>
<td>BDML&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.46 (0.21)</td>
<td>0.89</td>
<td>5.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LAC</td>
<td>-15.8</td>
<td>Average BD 95 plus BD5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.94 (0.12)</td>
<td>0.91</td>
<td>3.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LACB</td>
<td>-22.2</td>
<td>Average BD 95 plus BD5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.35 (0.18)</td>
<td>0.90</td>
<td>5.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LACL&lt;10</td>
<td>63.7</td>
<td>BD5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-2.54 (0.54)</td>
<td>0.79</td>
<td>5.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BL&lt;10</td>
<td>30.2</td>
<td>BD5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-1.43 (0.36)</td>
<td>0.73</td>
<td>3.6</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>HL5</td>
<td>-19.4</td>
<td>BD95&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.08 *(0.19)</td>
<td>0.84</td>
<td>9.7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>HL1</td>
<td>-12.3</td>
<td>BDmax&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.90 (0.10)</td>
<td>0.92</td>
<td>8.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BDML</td>
<td>6.4</td>
<td>MFD&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.88 (0.93)</td>
<td>0.44</td>
<td>6.7</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>BDML</td>
<td>60.7</td>
<td>Curvature&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-0.40 (0.16)</td>
<td>0.53</td>
<td>6.3</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>BD5</td>
<td>7.5</td>
<td>LAC&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>0.30 (0.04)</td>
<td>0.91</td>
<td>1.1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BD5</td>
<td>7.6</td>
<td>LACB&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>0.21 (0.03)</td>
<td>0.90</td>
<td>1.2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BD95</td>
<td>35.4</td>
<td>LAC&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>1.48 (0.24)</td>
<td>0.86</td>
<td>7.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BD95</td>
<td>35.8</td>
<td>LACB&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>1.01 (0.17)</td>
<td>0.85</td>
<td>7.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BDmax</td>
<td>29.6</td>
<td>LAC&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>2.55 (0.33)</td>
<td>0.90</td>
<td>10.0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BDmax</td>
<td>29.0</td>
<td>LACB&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>1.78 (0.22)</td>
<td>0.91</td>
<td>9.5</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

<sup>a</sup> MFD = mean fibre diameter.
<sup>b</sup> Adding MFD or fibre curvature (FC) provided no added predictive value
<sup>c</sup> Adding FC<sup>2</sup> or LAC<sup>2</sup> did not improve predictive value
Conclusion

There was a useful relationship between Baer Diagram hand array midpoint length and a range of Almeter length measurements. The Baer Diagram hand array midpoint length explained 77% of the variation in cashmere length after carding. The regression equation indicated a slope no different from one and a regression constant of –11. The addition of other objective measurements such as mean fibre diameter or fibre curvature did not improve the predictive value of the relationships.

Acknowledgments

Mr. Avtar Singh, Cashmere Connections Pty. Ltd., Bacchus Marsh, Victoria, Australia.

References