3

Cashmere, camelhair and other hair fibres

3.1 Introduction

The fibres discussed in this chapter include cashmere, camelhair and the species of *Lama*, the Angora rabbit and the yak. These fibres come from animals which mostly inhabit inhospitable regions of mountains and tundra where a highly protective fleece or fur is essential for survival. Some of the animals' habitats cover a range of altitudes and climates. Generally speaking, for a given species the higher the altitude and the sparser the food, the finer the fibre.

Table 3.1 gives a comparison of fibre characteristics and production figures. The fibres' combination of lightness and high thermal properties makes them exceptional, although some are produced in such small quantities that their contribution to the annual global tonnage is negligible.

Appendix 2 provides some unusual information on spider silk, which is not a hair fibre at all but a protein that makes a transition from soluble to insoluble once it has been extruded from the spider. The difficulties of harvesting the fibre are being overcome in a novel manner, and we hope that the reader will find the appendix interesting and informative.

Camelid fibres, as their name suggests, are produced by species of the camel family, the Bactrian camel (two-humped, as opposed to the Dromedary which has one hump) and the South American branch, llamas, alpacas, guanaco and vicuña. The last three, yak, musk ox and rabbit are in neither of these two groups. Apart from the Angora rabbit, all these animals live in areas where the climatic conditions are harsh, and range typically from well below freezing point at night to warm, or, in some cases, tropical conditions during the day.

As a result of the extremes of temperature under which they live, they have nearly all developed hair coverings consisting of an outer coat of coarser guard hairs which protects them from the sun, rain and dust and an undercoat of finer down hair which forms an insulating layer. The only two exceptions are the alpaca and the vicuña which, like the sheep, have an

Table 3.1 Luxury fibres: diameters, lengths, yield per animal, production and prices[8–11,14,18,23,25]

Fibre	Fibre diameter (μm)	Fibre length of down hair (mm)	Yield per animal (kg/yr)	Production (tonnes/yr*)	Price (US$/kg*)
Alpaca	20–36	200–550	3–5	4000–5000	2–10
Angora rabbit	14	60	0.42–0.82	3000	20
Cashgora	18–23	30–90	50 % of fleece	50	45
Camel hair	18–24	36–40	3.5–5	4500	9.5–24
Cashmere	12.5–19	35–50	0.10–0.16	9000–10 0001	100–130
Guanaco	14–16	30–60	0.70–0.95	10	150
Llama	19.38	80–250	2–5	2500–2750	2–4
Mohair	23–40	84–130	4–10	7000	7.5–8
Musk ox	11–20	40–70	0.9	3	
Silk		Filament	Not relevant	75000	22–20
Vicuña	12–15	30–40	0.2	5	360
Yak	15–20	35–50	0.1	1000	20

* Figures current at April 2001.

entire fleece made up of one kind of fibre only. As the valuable part of the fleece is the down, in those fleeces where both guard and down hairs are present, the two types of fibres need to be separated by a process called dehairing before the down can be spun. This is done either mechanically, or, now rarely, by hand.

Apart from dehairing, the spinning of these fibres follows traditional woollen processing for the shorter fibres and worsted processing for the longer fibres. However, all these fibres have smoother surfaces than wool because the outer scales of the fibres are less pronounced and more widely spaced. The crimp levels are also usually lower and in some cases are better described as curling or waviness. Fibre to fibre friction in yarn preparation and spinning will, therefore, be lower than that of wool, and carding and spinning conditions will need to be modified. Exactly what these modifications are will depend on the particular fibre or blend being processed and usually is confidential to each of the companies concerned.

The dehairing process is carried out before combing or carding and separates the down from the guard fibres. Exactly how each topmaker or spinner does this is still relatively confidential to each company. Variables might include the length and diameter of the fibres to be dehaired, the number of passes through cards that the fibres are given, the carding conditions, which additives are or are not used and the type of card clothing used. As a result of past help from the Japanese, China now manufactures its own dehairing machinery, and currently dehairs and spins its own cash-

mere and camel hair, and produces its own knitwear, mainly for export so as to considerably increase the added value of their original raw material.

All these fibres are keratin fibres, with chemical and physical compositions resembling those of wool. Because of their close chemical compositions, dyeing techniques, machinery and dyestuffs are similar to those used for wool, but because the smoother surfaces of these fibres reflect light differently when compared to those of wool it may be necessary to modify the dye recipes in order to obtain defined shades. The different surface structures of the fibres will also cause them to react differently during wet fabric finishing and this may require processing conditions to be modified. One major difference from wool is that most of these fibres are medullated to a greater or lesser degree and, in some cases, have microscopic air pockets within the fibre structure. This lightens the fibre and adds to its insulating properties.

A certain amount of scientific interest is being generated in the possibilities and advantages of interbreeding between the different races within both the goat and camelid groups. Examples that are well known are the huarizo and misti crosses between the alpaca and llama species, and more recently, cashgora (angora and certain races of feral goats; more information is given on cashgora in Section 3.2.6). Less well known are the experimental crosses between the dromedary and the guanaco[1] and between llamas and guanacos[2] where the advantage is said to be that the 'llamanacos' have inherited the domesticity of the llama and the beige and brown colours of the guanaco. It is also interesting to note the recent development of new textile products built on both the technical advantages of these protein fibres, particularly their inherent poor flammability, and their high image, aesthetics and comfort.

Dalton Lucerne Rare Fibres Ltd[3] have produced, and are continuing to develop, a range of wall coverings, curtains and blinds made from several of these expensive fibres that are aimed specifically at the private aircraft and luxury yacht market. These fabrics are based on the luxury hair fibres, sometimes mixed with silk or Sea Island cotton. Research associated with this project was presented in a recent conference paper, and this can be found in Appendix 11. The paper specifically describes how the fabrics have been meeting the stringent American fire safety regulations for aircraft.

The formal and authoritative identification of fibres has often been difficult, and Dr Hunter in chapter 15 of his book, *Mohair: A review of its Properties, Processing and Applications*,[4] provides extensive coverage of recent progress in the field of qualitative and quantitative identification of what are, chemically and physically, very similar fibres. As he states, this is an area of considerable commercial and legal importance and, whilst very considerable progress has been made by using modern techniques, the fact remains that the quantitative evaluation of the constituents of a blended

fabric containing, for example, wool and cashmere or mohair remains expensive, time-consuming and, to a greater or lesser extent, subjective, because it depends on the skill and experience of the operators.

Exactly the same problems are faced with blends of certain cellulosic fibres such as cotton, viscose, linen, ramie and hemp. It is therefore regrettable that work in this field initiated by Centexbel[5] in the late 1980s, using what was at that time advanced computer analysis, was abandoned due to lack of funding.

Our objective in this chapter is to cover down hairs only, although the coarser guard hairs are mentioned on several occasions as many of these do have textile applications, for example for tents, ropes and blankets. However, they are not traded to any significant extent on world markets and are not luxury fibres. They are therefore not treated in any depth.

3.2 Cashmere, Pashmina and Cashgora

The cashmere goat (*Capra hircus laniger*) and its fibre takes its name from Kashmir, which straddles the India–Pakistan frontier in the western Himalayas. At present little fibre is obtained from that area and cashmere is now principally produced in northern China, Mongolia, Tibet and Afghanistan. Smaller quantities are also produced in the Central Asian Republics, Iran, Australia and New Zealand.[5,8,12]

Figure 3.1 shows the cashmere goat. The height of these goats is between 60 and 80 cm. The male weighs on average 60 kg and the female, 40 kg, although those from the Gobi desert are smaller. Their average life span is about 7 years. The fleece is open, with long coarser outer hair and underhair or down. Each goat produces between 100 and 160 g of usable down per year.[8]

This down is very fine (12.5–19 μm), see Fig. 3.2. It has an average length of 35–50 mm. Table 3.2 gives more information on the fibre.

The fine down enables these goats to withstand the extreme winter cold of their original habitat, the plateaux of Central Asia. They protect themselves from overheating in the summer by shedding their down in the spring (see Section 3.2.1, harvesting).

3.2.1 Fibre production, harvesting and characteristics

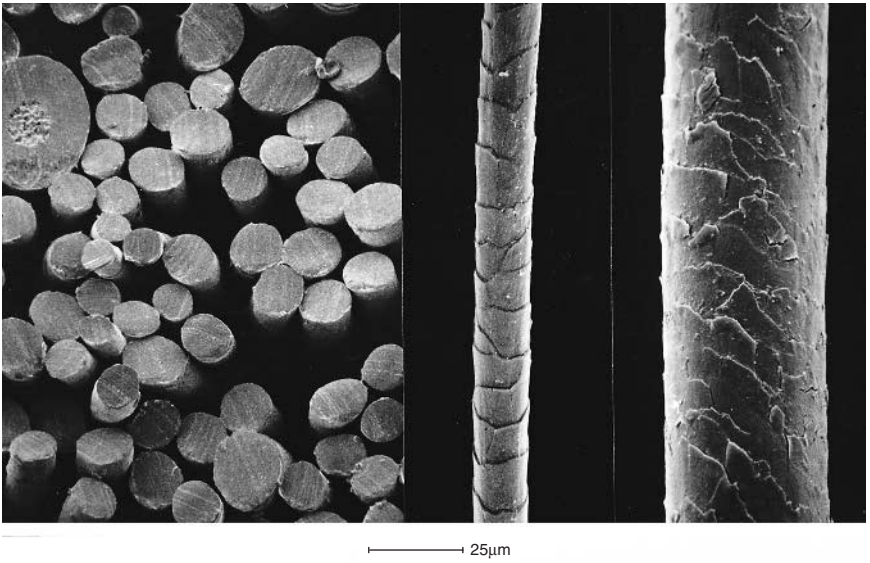
Of the world's production of 9000–10 000 tonnes, 50–60 % comes from China including Tibet, over half of which comes from Inner Mongolia, 20–30 % from Mongolia, and the balance from Iran and Afghanistan.[5] The other countries mentioned above produce only small quantities. Production in China and Mongolia has fallen by 10 % during the past few years due to

Table 3.2 Whole mount, cross-section and scale pattern of cashmere goat

Animal	Whole mount			Cross-section				Scale pattern		
	Profile	Medulla	Pigment distribution	Contour	Medulla	Cuticle	Pigment distribution	Base	Mid-length	Tip
Cashmere goat *Capra hircus laniger*	*Fine* Fairly regular diameter, scale margins prominent	None	Some sparsely pigmented	Almost circular	None	Thin	Fairly even	Regular waved mosaic, smooth; distant margins		
	Coarse Regular diameter, fairly prominent scale margins	Interrupted or continuous	Some fibres dense and even	Oval to circular, some flattened	Concentric	Thin	Dense in some fibres	Irregular waved mosaic, slightly crenate-rippled; near margins		Waved, crenate; near margins

Source: *Guide to the Identification of Animal Fibres*, H.M. Appleyard, by kind permission of BTTG, Wira House, West Park Ring Road, Leeds, LS16 6QL.

3.1 Cashmere goat reproduced from Pier Giuseppe Alvigini, *The Fibres Nearest the Sky*, Mondadore Editore, Verona, by kind permission of Mr Pier Alvigini at Alvigini S.A.S. 13900 Biella Via Dante, 12 Casella Postale 430, Italy.



3.2 Cashmere goat fibres, courtesy of Shirley Technologies, BTTG, Shirley House, Towers 2000 Business Park, Wilmslow Road, Didsbury, Manchester M20 2RB.

severe winter conditions. China is also attempting to control goat numbers because of overgrazing which causes desertification.[7]

In China and Mongolia, cashmere is harvested by combing during the three to six week spring period when the goats are moulting or by collecting the moulted fibres from the ground and bushes. In Iran, Afghanistan, Australia and New Zealand the fleece is usually shorn.[5,8]

The hair is sorted by hand for grades and colours (white, grey and brown). This is done quickly and requires considerable expertise, and reduces the amount of guard hair. After sorting, the different piles of hair are 'willowed', which entails putting the fibres through a simple revolving machine to shake out much of the dust and grit. After sorting and willowing the fibres are scoured before being dehaired.[9]

The quality of the dehaired fibre is assessed by the diameter, colour and length and the coarse hair content. Diameters are within the range of 14–19 μm and the fibre lengths measure from 150 to 450 mm.[5] Chinese cashmere is considered to be the best quality, has a fibre diameter of 14–16 μm,[5] and is predominantly white. Cashmere fibres are shown in Fig. 3.2.

The standard of the Cashmere and Camel Hair Institute (CCMI) of the USA is 18.5 μm ± 0.5 μm. Cashmere produced in Mongolia is generally slightly coarser than the Chinese fibre, its diameter being 16–17.5 μm. Due to cross-breeding for increased yield, some Mongolian fibre is increasing in

diameter, with consequent loss of quality. Cashmere from New Zealand and Australia is in the 16–18.5 µm range; that from Iran and Afghanistan in the 16–19.5 µm range.[5] Experience has shown that cashmere goats raised in more benign climates do not produce such fine down as they do in their native habitat, although the fibres are still very soft when compared to many other animal fibres. For further details concerning cashmere fibres of differing origins see the paper by Phan and Wortmann presented at the 7th international conference on goats which is reproduced in Appendix 10.[12]

3.2.2 Prices and manufacture

Fine white knitting quality cashmere is in the US$120–130 per kg range, lower qualities from US$100 to 110 per kg. This is an increase over prices in December 1998 and January 1999.[7]

The overriding influence on the price is the mean fibre diameter. For example, Iranian and Afghan cashmeres have diameters 2–3 µm greater than Chinese cashmere and are 40–50 % cheaper.[5] Colour is also an important factor, white being the most valuable because it can be used not only as it is but can be dyed to the pastel shades which are often required for knitwear.[12] Brown is the least valuable colour because it can only be dyed to dark shades.

Fleeces have to be dehaired to separate the two kinds of fibres before the down fibres are spun, as with others that have both guard and down hairs. A dehairing process specifically for cashmere was developed in the 1870s by Joseph Dawson, founder of Dawson International which is still a major operator in the luxury fibre field. All hair fleeces which contain both guard and down fibres are dehaired and the process is discussed (see p. 134) as far as it can be, bearing in mind the confidentiality that still surrounds the operation. Spinning can be on either the woollen or worsted system, depending on the lengths of the fibres and the end-use envisaged. (More information is given in the section on marketing and end-uses, 3.2.4.)

3.2.3 Distribution

The Chinese government's liberalisation of the economy in the mid 1980s led to a somewhat chaotic period during which prices rose, quality dropped and it was difficult and complicated to obtain supplies. This resulted in a decrease in knitwear sold which Dawson International, a knitwear manufacturer and major buyer of fibre, estimated at 30 %. To re-establish order, both in fibre distribution and quality standards, the Chinese government instituted regulations in 1989 to raise the quality of exported commodities, backed by mandatory testing, and in 1990 established a Cashmere Foreign

Trade Centre to manage exports. This Centre organises four trade fairs each year to sell cashmere and sets limits to export prices.

In 1991 the Chinese government issued a further regulation to the effect that all textile products from China required labels of origin, could not exceed quota restrictions and could only be exported to countries which had signed bilateral trading agreements.[13] However, with the general opening up of Chinese trade, the cashmere market is no longer controlled, and the buying and selling of cashmere is now open to everyone.

The physical distribution of the fibre is similar to that of camelhair but with the difference that many Chinese companies produce cashmere knitwear and distribute that globally.[7] There is also an internal market for cashmere knitwear in China.[5]

3.2.4 Marketing and end-uses

The largest part of fibre production is used in fine woollen spun yarns for knitwear in Scotland, knitted on fully fashioned frames. Both woollen and worsted yarns are used for woven fabric. Cashmere is frequently blended with fine merino wools to produce softer handling fabrics which are somewhat cheaper than 100 % cashmere but still have some of the cashmere 'image'.

Until fairly recently the two principal manufacturing countries of these high-priced articles were Scotland and Italy, but in the late 1980s China and Mongolia set up their own spinning and knitting operations using dehairing technology which they had developed in co-operation with Japanese companies.[12] They increased production and although the knitwear produced was not as good in quality as the Scots and Italian merchandise, it was cheaper. However, luxury markets such as these depend not only on good marketing and on the quality of the goods provided but also, to some extent, on their scarcity value.

The market was, therefore, disrupted but in addition, as the supply of cashmere fibre is limited, Scots and Italian manufacturers experienced difficulty in obtaining adequate quantities of quality raw material. European manufacturers responded by setting up joint ventures with Chinese partners in China. To a large extent this solved the supply problem, and the quality is currently being raised by improvements to Chinese production methods.[5] Scots manufacturers are also defending their markets by expanding further their product lines and developing their retail networks and promotion.[13]

For further information and, in particular, a more detailed account of developments in the cashmere trade between 1990 and 1996 due to developments within China, see 'Scotland and China and the Cashmere Trade' by Theresa Purcell, reproduced in Appendix 9.

With such highly priced and high image products it is scarcely surprising that adulteration occurs, where cashmere is blended with wool or other fibres.[12] The CCMI's policy in this area is to buy articles on the open market and analyse them in order to establish whether their fibre content is in keeping with the label on the garment.[8]

Cashmere garments and fabrics are mainly manufactured in the United Kingdom and Italy but there are also three companies in the USA which specialise in this niche market. Cashmere garments are distributed throughout the world but, as with many luxury products, the major markets are the USA, Japan and western Europe.[5] Although less important than knitwear, woven fabrics for men's and women's outerwear is also an important outlet. Again, the principal consumer markets are the USA, Japan and western Europe. The outer guard hairs are used in carpets and underfelts.[9]

3.2.5 Pashmina

The name 'pashmina' seems to be used rather loosely, and it is sometimes difficult to separate myth from fact regarding the origins of the fibre. Pashmina has, on occasion, been claimed to come from the ibex, but that is unlikely and it is generally accepted to be fine quality Indian cashmere.

Originally, pashmina shawls and scarves were produced in Kashmir from hand-spun and woven fine cashmere fibre that was gathered from the ground and bushes where the goats had been feeding. India is not a significant producer of cashmere fibre but in Kashmir there are shawls of great fineness and softness which have been in families' possession for generations, and many such shawls are still produced locally. These articles are expensive, even by cashmere standards, but are now available on European and American markets. Some, but not all, alleged pashmina shawls on the market contain wool, and some, described as pashmina, actually originate from areas other than Kashmir but are sold by suppliers who use the words pashmina and cashmere synonymously. This has naturally led to a certain amount of confusion in the market place!

3.2.6 Cashgora

Cashgora is the name given to the fibre produced by cross-breeding the Angora goat (producer of mohair) with another type of goat. It is difficult to be specific about what type of goat because the following are mentioned in the literature: feral goats in New Zealand, cashmere goats,[12] the Anglo-Nubian and dairy goats.[10] It is not surprising, therefore, that the fibre has a mixed reputation in the industry because with such varied parents its characteristics are unlikely to be constant.

Cashgora raised a considerable amount of interest in the industry in the last half of the 1980s and, possibly because of this reason, in 1988 the International Wool Textile Organisation accepted 'cashgora' as a generic term for fibres produced by the mohair–cashmere cross.

The author is indebted to Dr L Hunter for the following information about this fibre and its uses. Length, 30–90 mm[24,25] (the goats are shorn twice a year); diameter, 18–23 μm. The down represents approximately 50 % of the mass of the fleece.

Dr Hunter also indicates that Phan et al. examined the morphological features of the fibres and are of the opinion that they are closer to mohair than cashmere but that some fibres possess cashmere-like features (cylindrical and semi-cylindrical scales) and others some characteristics of mohair with 'splits', lance-shaped scales and subscales.[26,27,28] The fibres have a low level of lustre.

There are three types of cashgora, ranging from that at the top end (18.5 μm), marketed as 'Ligne Or', that at the medium range (20 μm), marketed as 'Ligne Emeraude' and cashgora at the lower range (22 μm), marketed as 'Ligne Saphir'.[29]

At René Friedlin, the French dehairer, cashgora is classified into three classes according to diameter: 17–18.5 μm, 19.5–21 μm and 22–23 μm.[30] In April 2001 the price for 20 μm cashgora was US$45/kg.[6] Cashgora was used in many articles of clothing (light-weight suits and jackets, coats, scarves, stoles);[26] with the exception of underwear and socks it is considered more suitable for weaving than for knitting.[30] Albertin et al.[31] compared the behaviour of cashgora and cashmere during finishing operations.

The market's initial enthusiasm for the new fibre was not maintained; while in 1990 global production was estimated at 200 tonnes, in 2000 it was estimated at 60 tonnes.[6]

3.3 Camelhair

The *Camelus* is part of the Caelidae grey family. Practically all camelhair is produced from the two-humped Bactrian camel which is found mainly in Mongolia and Northern China, in areas bordering on the Gobi desert where the camel feeds on the bitter vegetation rejected by other species and is illustrated in Fig. 3.3. It is very partial to salt, and will happily drink from salt lakes and brackish water.

As with other animals that produce textile fibres, with the notable exceptions of sheep, alpaca and the Angora goat, the camel grows two kinds of hair, an outer protective coat of coarse (guard) hair and an insulating undercoat of fine hair or down. The down produced by camels living in the hotter desert areas tends to be coarser and sparser than from those living in more temperate areas. Some camelhair is also produced in Tibet, Afghanistan,

3.3 Bactrian camel reproduced from Pier Giuseppe Alvigini, *The Fibres Nearest the Sky* (2nd ed. 1984), Mondadori Editore, Verona, by kind permission of Mr Pier Alvigini at Alvigini S.A.S. 13900 Biella – Via Dante, 12 Casella Postale 430, Italy.

Iran, Russia, New Zealand and Australia.[8,9] The Bactrian camel is used as a means of transport for people and goods, occasionally for sport as well as a source of textile fibres.

3.3.1 Fibre production, characteristics and harvesting

World production has been documented in the past at 4500 tonnes of greasy hair[7] (other estimates put present production somewhat lower, at 3000–3500 tonnes[6]). Production is evenly divided between China (Inner Mongolia, Xinjiang, Gansu and Ningzia)[5] and Mongolia, and has been decreasing over the last decade, principally because, in Mongolia, Bactrian camels are being replaced by motor transport as carriers of goods.[6] Fibre colours range from pale reddish to light brown, Chinese hair tending to be lighter in shade and finer than Mongolian hair.[9] White fleece is the most valued but is very rare.

The camel moults in late spring or early summer when the fibres form matted tufts which hang down from the head, sides, neck and legs. The fibres are harvested by pulling or by gathering the clumps shed onto the ground. Fibres are also obtained by shearing but the hair covering the humps is not shorn as this may make the animals more susceptible to disease.[8,9] The whole mount, cross-section and scale pattern of the camel are shown in Table 3.3.

Table 3.3 Whole mount, cross-section and scale pattern of camel

Animal	Whole mount			Cross-section				Scale pattern		
	Profile	Medulla	Pigment distribution	Contour	Medulla	Cuticle	Pigment distribution	Base	Mid-length	Tip
Camel *Camelus bactrianus*	*Fine* Regular diameter, smooth	None or fragmental	Diffuse, sometimes streaky	Circular to oval	Circular	Thin	Sparse and towards the centre	Waved mosaic, smooth; near to distant margins		
	Coarse [Guard] Regular diameter, smooth	Continuous, fine lattice	Some dense, streaky	Oval to circular	Oval to circular	Thin	Dense near medulla becoming less dense towards the cuticle	Irregular waved, smooth; near margins	Irregular waved, crenate-rippled; near to close margins	Irregular waved, crenate; near margins
	Intermediate thickness Regular diameter, smooth	Continuous, fine lattice	Some dense, streaky	Oval to circular	Oval to circular	Thin	Dense near medulla becoming less dense towards the cuticle	Irregular waved mosaic, smooth; distant margins		Irregular waved, crenate; near margins

Source: Guide to the Identification of Animal Fibres, H.M. Appleyard, by kind permission of BTTG, Wira House, West Park Ring Road, Leeds, LS16 6QL.

After harvesting, camelhair is bought directly from the herders by middlemen who in turn sell to larger merchants and dehairers, and the hair is sorted according to colour and the age of the animal. It is then sold to private or state-run companies and eventually finds its way to spinning and weaving mills in the USA, Japan and Europe.[7]

The coarser fibres such as the camel manes from Mongolia and third-grade Chinese camel are carded on fairly coarse carding machinery, and thoroughly gilled prior to Noble combing. Owing to the large number of impurities which may not be entirely removed in scouring, a second combing process is sometimes required. The extremes of length found in this type of material usually necessitate the introduction of a 'reducing' process before combing. This, in effect, breaks the longer fibres to the required length, and the short tips held in the sliver are removed, together with the noil, during the combing process. Medium qualities are usually processed in the same way as alpaca but better qualities have to undergo a much finer type of carding operation, and the combing is done on a Noble comb of similar pin action to that used for Merino wool.

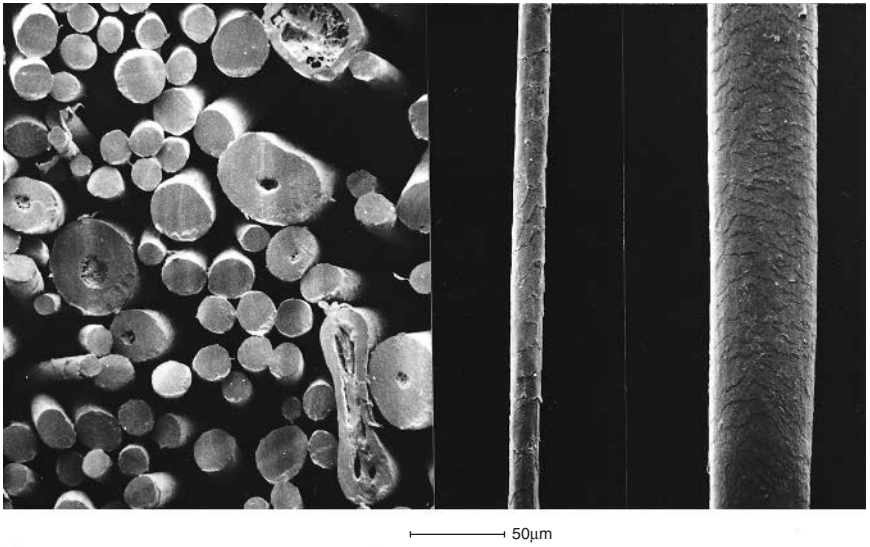
Frequently, to achieve a greater fineness and lustre, the fibres are combed again on a Lister comb, and the large noil which represents the bulk of the finest fibres is used again as the raw material for carding and combing to produce a 'superfine top'.

Dehaired down fibre diameters range from 16 to 20 μm, intermediate hairs from 20 to 29 μm and guard hairs from 30 to 120 μm. Baby camelhair, which is the finest and the softest, has a diameter of about 16–17 μm (see Fig. 3.4). Fibre lengths of down fibres range between 36 and 40 mm,[5] and guard hairs can reach up to 37.5 cm. The length of baby camelhair is similar to that of adults.[9] The average yield of an adult female's under hair is 3.5 kg, of a male's, 7 kg.[9] Prices for dehaired, knitting grade down hair are around US$24 per kg, dehaired first weaving grade down around US$12–13 per kg, and dehaired second weaving grade qualities are around US$9 per kg.[5]

3.3.2 End-uses

The colour range is limited by dyeing to mid- and darker shades although most fabrics are produced in the fibres' natural colour, known as 'camel'. Some is dyed to a darker shade of brown. The principal end-uses are overcoatings and jacket weights.[5]

The principal manufacturing and consumer market is the USA, which accounts for 70 % to 75 % of fabric production.[7] Some camelhair and camelhair-blended fabrics are also produced in the UK, Italy and Japan. In Europe the finer qualities of camelhair are also used, to some extent, in knitwear, mainly for men. A market is developing in Italy for baby camelhair as an alternative to cashmere in knitted garments[10] but knitwear accounts for only a very small share of the total market.



3.4 Camel fibres, courtesy of Shirley Technologies, BTTG, Shirley House, Towers 2000 Business Park, Wilmslow Road, Didsbury, Manchester M20 2RB.

Within the areas of fibre production, guard hairs are used for ropes, tentings, carpet backing, bedding and heavy outer garments. The traditional tents and outer garments used by the nomadic peoples of Central Asia are made from felted outer hair [9,10] or wool.

3.4 Alpaca fibre

The alpaca (*Lama pacos*) were domesticated in the altiplano some 6000 years ago for their meat and for their fibres. Adult alpaca weigh about 65 to 80 kg and grow to 90 cm tall (see Fig. 3.5). They live for up to 20 years and are productive for about 10. Unlike most other mammals from which luxury fibres are obtained, but like the Angora goat (which supplies mohair) and of course sheep, the alpaca has a complete fleece and does not produce both guard and down hairs.[14,15,16] Their habitat is the Andean altiplano, at altitudes of between 3000 and 5000 metres where temperatures vary from – 25 °C at night to +18 °C during the day.[17]

3.4.1 Fibre production and prices

Of the present population of approximately 4 million alpacas some 80 % are in Peru. Total annual production is between 4000 and 5000 tonnes of greasy fibre.[16,17] Alpaca is by far the most important of the Camelid fibres,

3.5 Alpaca by kind permission of Mr F.C. Wilson, The Alpaca Centre, Snuff Mill Lane, Stainton, Penrith, Cumbria.

Table 3.4 Alpaca population, 2000[18]

Country	No. of Alpaca
Peru	3500000
Bolivia	350000
Chile	40000
Argentina	5000
Ecuador	5000
USA	15000
Canada	10000
Australia	20000
New Zealand	5000
UK	5000
Total	3955000

in both quantity and value. The average percentage of clean yield is 85–90.[16] Table 3.4 shows the alpaca population for various countries.

In Peru 80 % of the Alpaca production is concentrated in the southern region of Puno.[9] The populations in the new countries of breeding, the USA and Australia in particular, are growing, but from a small base. The Peruvian population has been relatively static due to the economic restrictions

on the smallholding farmers in the Andes. Most studies agree that an economically viable herd size for alpaca is around two thousand head, yet the average Peruvian farming unit only tends between ten and twenty animals.[16]

The different types of alpaca are:

- Huacayo: This is the most common type – about 80 % of the total.
- Suri: Silky haired animal, with long fibres – about 10 % of the population.
- Huarizo: A 'mule', the result of a crossing between a male llama and a female alpaca.
- Misti: A 'mule', the result of a crossing between a male alpaca and a female llama.[16]

A cria is a baby alpaca, under one year old.

Alpaca fibre is soft, lustrous, fine and durable. The fibre is tubular and medulated.[9,10] The fibre diameter lies between 20 µm and 36 µm.[9,16] Fibre lengths after shearing are as follows: huyacaya – 25 to 30 cm; baby huyacaya – 20 to 25 cm and suri – 50 to 55 cm. Average greasy hair prices in 2000 were US$ 2 to 10 per kg.[16]

Table 3.5 gives various details about alpaca fibre.

3.4.2 Fibre harvesting, preparing and processing

Alpacas are shorn, on average, every 18 months.[16] Each animal produces approximately 3.5 kg of hair as a rule but this varies from below 3 kg for the cria to 5 kg for the adult animals. The new fibre comes on to the market in October, and the shorn fleeces are classed into ten[9] colour categories – white, grey, fawn, light brown, dark brown, black, roan, brown and white, black and white and spotted (or mixed colours).[17]

Fleeces are separated into less than one year old cria, tui (1–2 year old), and adult. They are then sorted into (a) premier fleece (back, side, part of shoulder and rump), (b) neck, (c) oddments (apron, belly, legs), or (d) pieces (head, shankings, tail and other extreme hairy pieces) within each colour category. Premier fleeces are graded according to fineness into baby (<22 µm), extra fine (22.0–24.9 µm), medium fine (25.0–29.9 µm) and coarse (>30 µm) categories. See Fig. 3.6. Extremely coarse guard hair and kempy fleeces are also separated from the main lots.[9]

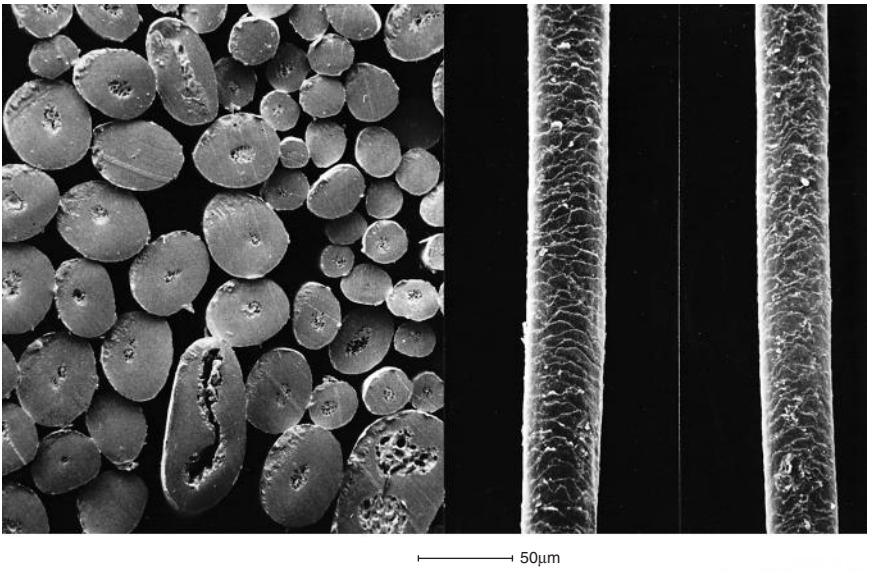
Fleeces that were not shorn as crias have longer fibres, while late-born crias have shorter fleeces when shorn with the older crias. Fleeces are therefore also sorted for length into short (<60 mm), medium (60–120 mm) and long (>120 mm) grades.

The fibres are combed on rectilinear combs, ratio of top to noils being about 90/10.[16]

Table 3.5 Whole mount, cross-section and scale pattern of alpaca

Animal	Whole mount			Cross-section				Scale pattern		
	Profile	Medulla	Pigment distribution	Contour	Medulla	Cuticle	Pigment distribution	Base	Mid-length	Tip
	Fine									
Alpaca *Lama pacos*	See Llama	More non-medullated fibres than in Llama	Varies from sparse to very dense, some streaky	See Llama	See Llama	Fairly thick	Sparse to very dense, most dense towards the cuticle. Some very large aggregates	See Llama		
	Coarse									
	See Llama	Continuous fine lattice (granular appearance)	Varies from sparse to very dense, some streaky	See Llama	Fewer fibres with bi-partite medulla than in Llama	Fairly thick	Sparse to very dense, most dense towards the cuticle. Some very large aggregates	See Llama		

Source: *Guide to the Identification of Animal Fibres*, H.M. Appleyard, by kind permission of BTTG, Wira House, West Park Ring Road, Leeds, LS16 6QL.



3.6 Alpaca fibres, courtesy of Shirley Technologies, BTTG, Shirley House, Towers 2000 Business Park, Wilmslow Road, Didsbury, Manchester M20 2RB.

3.4.3 Markets

Tops, noils, yarn woven fabric and knitwear is exported from Peru, but no fibre. These products are exported to countries and excellent yearly export statistics are provided by COMEX (External Peruvian Commerce). In 2000, the major export markets were China, Italy, the UK, Germany, and Switzerland. The total value FOB of these exports was US$63.4 million, 5754 tonnes in weight plus 34 400 m^2 of woven fabric.

3.4.3 End-uses and consumer markets

Alpaca's principal end-uses are in knitwear and light-weight suitings. The major consumer markets are the USA, Japan, and Italy but it is also interesting to note that Spain, Bolivia, Colombia and the UK import substantial quantities of woven fabric, and Australia and Argentina also import substantial quantities of knitwear.

3.4.4 Fire retardancy

Dalton Lucerne Rare Fibres Ltd have currently obtained grants to research the fire science of natural fibres, including alpaca, and the excellent properties of fire resistance should open up markets where high standards of

3.7 Llama reproduced from Pier Giuseppe Alvigini, *The Fibres Nearest the Sky*, Mondadori Editore, Verona, by kind permission of Mr Pier Alvigini at Alvigini S.A.S. 13900 Biella Via Dante, 12 Casella Postale 430, Italy.

fire protection are required. (See Appendix 11.) Experimental cloths are being woven for the company by Bradford Industrial Museum in the UK on looms similar to those used by Titus Salt in the 1800s. With cotton, silk or polyester warps, the handle of the fabrics is exceptionally pleasing.

3.5 Llama fibre

The llama (*Lama glama*) is similar in build to the alpaca but is larger, averaging 1.2 cm at the shoulder and weighing around 110 kg. (See Fig. 3.7.) These animals are genetically very close and can interbreed to produce 'mules', the huarizo and the misti. Like the alpaca, they are domesticated and probably have been so for 6000 years. They are used to carry goods (and need no saddles to protect their backs as their fleece acts as a cushion) and are the main means of transport in the mountainous areas of Bolivia and Peru, for their meat, their hides, their hair and their dried dung which is used as fuel.[10,18] Table 3.6 gives some important details about the llama and Table 3.7 their distribution.

There are two types of llama – kcara, a light-fleeced animal used mainly as a beast of burden and chaku, a heavy-fleeced animal used for its hair.

3.5.1 Fibre production, preparation and harvesting

In South America, where their diet is almost completely protein free, the llamas' outer coat of guard hairs may reach 20 % of the total fleece weight.

Table 3.6 Whole mount, cross-section and scale pattern of llama

Animal	Whole mount			Cross-section				Scale pattern		
	Profile	Medulla	Pigment distribution	Contour	Medulla	Cuticle	Pigment distribution	Base	Mid-length	Tip
Llama	*Coarse* Regular diameter, smooth	Continuous, ofter bi- or multipartite	Varies from sparse to very dense, some streaky	Varies – circular, oval, triangular or polygonal	Varies – circular, bi- or multipartite	Fairly thick	Sparse to very dense, most dense towards the cuticle. Some very large aggregates	Irregular waved mosaic, smooth; near margins	Irregular waved, rippled-crenate; close margins	

Source: *Guide to the Identification of Animal Fibres*, H.M. Appleyard, by kind permission of BTTG, Wira House, West Park Ring Road, Leeds, LS16 6QL.

Table 3.7 Llama population

Country	No. of Llama
Bolivia	950 000
Peru	250 000
USA	135 000
Argentina	30 000
Ecuador	20 000
Canada	15 000
Chile	15 000
Australia	10 000
UK	8 000
Total	1 433 000

Greasy hair annual production is between 2500 and 2750 tonnes, with an average greasy to clean yield of 85–90 %.[16] In the US where the animals' food may contain as much as 15 % protein, the fleeces have little, if any, guard hairs and the average fibre diameter is lower than in Bolivia. Although usually white, the down hairs can be brown, grey or black. The fleeces may be of one colour or mixed.[10,18]

Whilst a method of machine shearing has been developed in Peru by R Dunick of the New Zealand Wool Board,[9] hand-shearing is still common. Hair growth is normally between 70 and 100 mm per year, and fleeces weigh 2–5 kg. The animals are usually shorn every two years. Fibre lengths range from 80 to 250 mm[8] and fibre diameters are in the range of 19–38 μm.[16] Llama fibres are depicted in Fig. 3.8. Llama is dehaired in Bolivia as well as in Europe. The average greasy hair prices in 2000 were US$2–4.

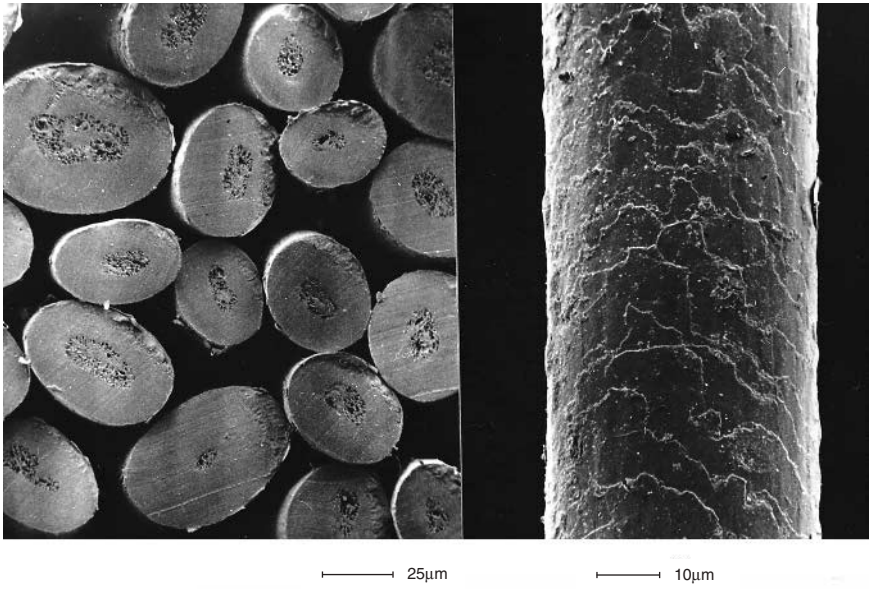
3.5.2 End-uses

Very few statistics are available from Bolivia, the major producing country. Llama fibre is used, alone and in blends, for knitwear and outerwear. The guard hairs are used for ropes, braids, carpets and some coarse clothing.[16]

3.6 Vicuña fibre

The vicuña (*Vicugna vicugna*) is the smallest of the Camelids, with a shoulder height of about 90 cm and a weight of about 50 kg. (See Fig. 3.9.) Its natural habitat lies in the semi-arid grasslands of the central Andes at altitudes of 3600–5000 metres on the snow line, an important factor in its fibre production, with average daytime temperatures of +20 °C, dropping to –15 °C at night. Its life expectancy is about 20 years.

Prior to the Spanish invasion of South America in the seventeenth century, vicuña fleeces were reserved for the Inca royal family, at which time it was



3.8 Llama fibres, courtesy of Shirley Technologies, BTTG, Shirley House, Towers 2000 Business Park, Wilmslow Road, Didsbury, Manchester M20 2RB.

3.9 Vicuña reproduced from Pier Giuseppe Alvigini, *The Fibres Nearest the Sky*, Mondadori Editore, Verona, by kind permission of Mr Pier Alvigini at Alvigini S.A.S. 13900 Biella Via Dante, 12 Casella Postale 430, Italy.

said that there were two million vicuñas in the high Andes. After the demise of the Incas, fibre harvesting was no longer organised and the market was supplied by killing the animals for their fleeces. Over 300 years, this led to the near-extinction of the species. In 1969, barely 5000 vicuñas were left.

In 1972, the Peruvian government started strictly to enforce the laws which forbade the use of vicuña hair and the hunting of the animals. By 1987, the number of vicuñas had recovered to around 50 000, and the government agreed to a trial commercialisation of the hair in woven cloth only. In 1994, the population had risen to 66 500 and the government set up a competition to commercialise the hair in ways which would benefit the highland farming communities, the manufacturer and the government. In 1999 there were 140 000 vicuñas in Peru. It is estimated the number will have increased to 165 000 by 2000. In addition there are an estimated further 55 000 in northern Chile, Bolivia and Argentina. Providing that the ecological balance can be maintained in the highlands, there is no reason why the number of vicuñas should not return to the two million figure of the time of the Inca.

3.6.1 Fibre characteristics

The fibre range is from 12 to 15 μm, averaging at 13 μm, which is amongst the finest animal hairs produced. The fibre length is in the range of 20–25 mm. Table 3.8 gives relevant statistics about the vicuña and Fig. 3.10 depicts the fibres.

3.6.2 Fibre harvesting, processing and price

Vicuñas are not domesticated and the majority are in Pampas Galeras, a national reserve in the Ayacucho region of Peru's altiplano. Today the fibre is harvested much as it was in Inca times. The animals are herded into the end of a valley with very steep sides that prevent them from escaping. Just before the closed end of the valley, nets are placed so as to form small separate areas with openings which only allow one vicuña to enter at a time. When inside these pens, the animals are sheared.

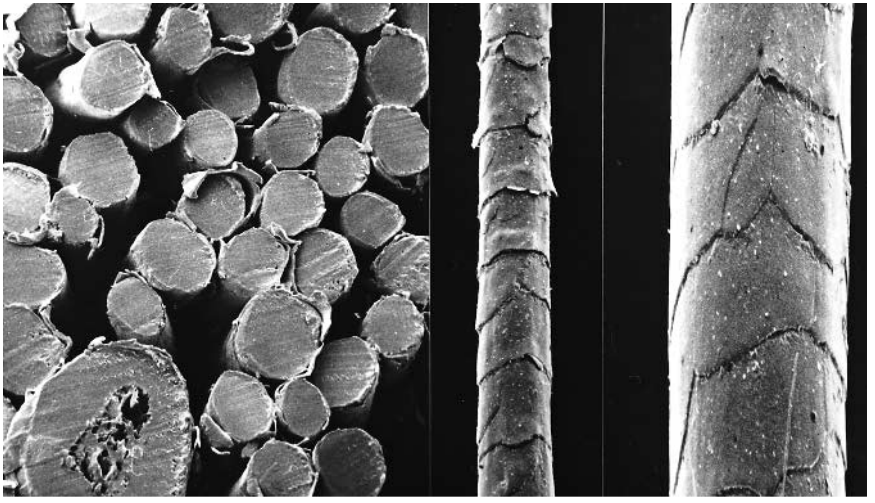
The vicuña has only a low percentage of fine and usable hair in its fleece, and is shorn once every 18 months. Yields vary from 85 to 550 g, with an average of 200 g per vicuña. This fine hair comes from the area just behind the front legs of the animal. Total annual production of greasy hair is expected to be around 5000 tonnes in 2000. The lack of greater quantities is attributed to two main factors:

- As the vicuña is not a domesticated animal, not all the population is penned for shearing every year.
- Fine and coarse hair are intermingled in the shorn fleece, and subsequent separation generally results in high wastage and a poor yield.

Table 3.8 Whole mount, cross-section and scale pattern of vicuña

Animal	Whole mount			Cross-section				Scale pattern		
	Profile	Medulla	Pigment distribution	Contour	Medulla	Cuticle	Pigment distribution	Base	Mid-length	Tip
Vicuña *Vicugna vicugna*	*Fine* Regular diameter, scale margins protrude slightly	Interrupted	Varies from sparse to very dense, some streaky	See Llama	See Llama	Fairly thick	Sparse to very dense, most dense towards the cuticle. Some very large aggregates	See Llama		
	Coarse See Llama	See Llama	Varies from sparse to very dense, some streaky	See Llama	See Llama	Fairly thick	Sparse to very dense, most dense towards the cuticle. Some very large aggregates	See Llama		

Source: *Guide to the Identification of Animal Fibres*, H.M. Appleyard, by kind permission of BTTG, Wira House, West Park Ring Road, Leeds, LS16 6QL.



3.10 Vicuña fibres, courtesy of Shirley Technologies, BTTG, Shirley House, Towers 2000 Business Park, Wilmslow Road, Didsbury, Manchester M20 2RB.

Once dehaired, the greasy to clean yield is 65–70 %. Average greasy hair price: US$360/kg.

In order to extract as much of the fine hair as possible from the shorn fleeces, a prolonged manual classification process is employed in Peru. The fibre is sent to Italy for dehairing as the appropriate machinery is not yet available in Peru. As well as being dehaired in Italy most of the vicuña fibre available is also spun and woven in that country. The fibres' natural colour is fawn which limits the colours obtainable by dyeing, as only darker shades can be produced. Vicuña is the most expensive apparel fibre.

3.6.3 End-uses and markets

Because of the length of the fibre (20–25 mm), vicuña is usually woollen spun but when blended with wool, worsted spinning becomes practicable. The woollen yarns produced currently are Tex 55-25 which are woven into suitings (430 g/m), jacketings (550 g/m), overcoatings and scarves. The principal consumer markets for the fabrics are Japan (45 %), Italy (35 %), UK (10 %) and the USA (10 %).

3.7 Guanaco fibre

The guanaco (*Lama hunchus* or *Lama guanicoe*)[16] is the smallest species of llama, and being more aggressive than the vicuña, it is not domesticated. Its habitat is extremely wide and ranges from the snowline down to sea level

3.11 Guanaco reproduced from Pier Giuseppe Alvigini, *The Fibres Nearest the Sky*, Mondadori Editore, Verona, by kind permission of Mr Pier Alvigini at Alvigini S.A.S. 13900 Biella Via Dante, 12 Casella Postale 430, Italy.

Table 3.9 Animal population, Guanaco

Country	No. of Guanaco
Argentina	500 000
Peru	90 000
Chile	10 000
Total	600 000

from Peru to Tierra del Fuego. Adult guanaco stand at about 110 cm high. (See Fig. 3.11.)

3.7.1 Fibre harvesting, production and price

The guanaco population has grown in the last two or three years by about 5 % as more commercial interest is awakened in its potential; its distribution is given in Table 3.9. The fibre is harvested in the same way as is the vicuña's. Total greasy hair production is around 10 tonnes/yr, and greasy to clean yield is 65 to 70 %. Average greasy hair price: US$150/kg.

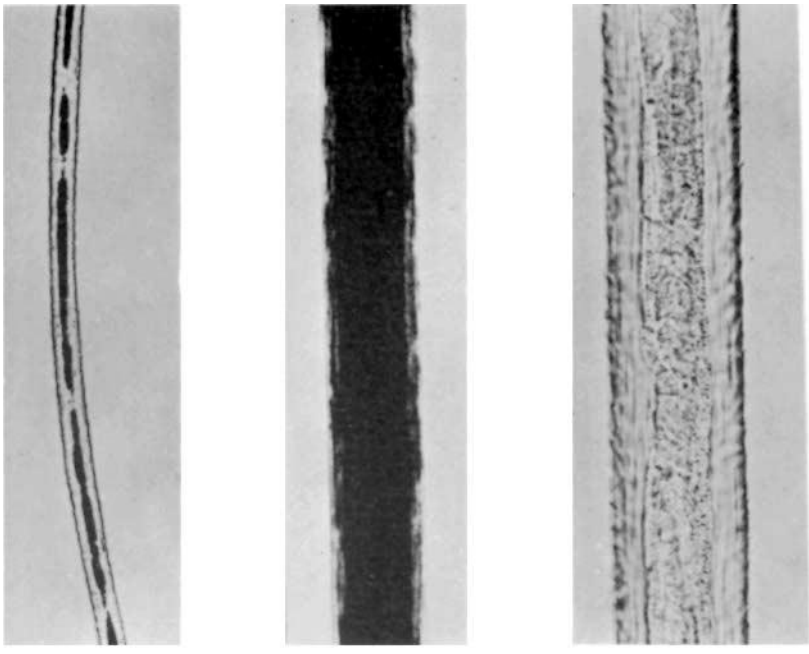
3.7.2 Fibre characteristics

These are outlined in Table 3.10. Fibre μm range is 14 to 16 μm. Figure 3.12 shows the guanaco fibres, magnified.

Table 3.10 Whole mount, cross-section and scale pattern of guanaco

Animal	Whole mount			Cross-section				Scale pattern		
	Profile	Medulla	Pigment distribution	Contour	Medulla	Cuticle	Pigment distribution	Base	Mid-length	Tip
Guanaco *Llama glama huanacus*	*Fine* Regular diameter, scale margins protrude slightly	None, interrupted or continuous	Varies from sparse to very dense, some streaky	See Llama	See Llama	Fairly thick	Sparse to very dense, most dense towards the cuticle. Some very large aggregates	See Llama		
	Coarse See Llama	See Llama	Varies from sparse to very dense, some streaky	See Llama	See Llama	Fairly thick	Sparse to very dense, most dense towards the cuticle. Some very large aggregates	See Llama		

Source: *Guide to the Identification of Animal Fibres*, H.M. Appleyard, by kind permission of BTTG, Wira House, West Park Ring Road, Leeds, LS16 6QL.



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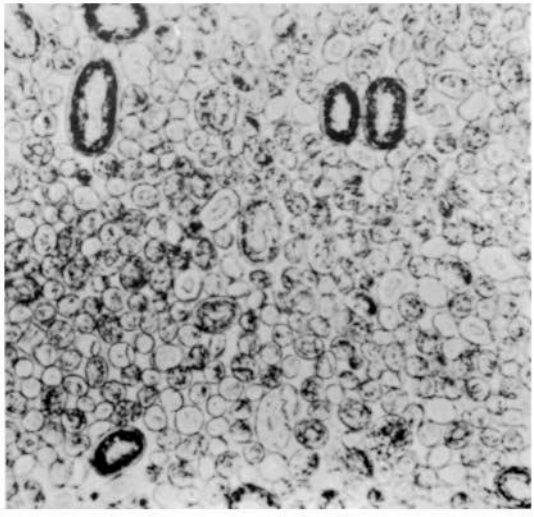

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3.12 Guanaco fibres: (a) fine fibre, whole mount, 200×; (b) coarse fibre, whole mount, 200×; (c) coarse fibre mounted in lacto-picro phenol to show granular medulla, 400×; (d) cross-sections, 200×. Reproduced from H.M. Appleyard. *A Guide to the Identification of Animal Fibres* (2nd ed. 1978), by kind permission of BTTG, Wira House, West Park Ring Road, Leeds LS16 6QL.

3.7.3 End-uses and markets

Little information is available but it is clear that the end-uses will be similar to those of vicuña, as will be the markets. The principal markets for the cloths are Japan (50 %), Italy (45 %) and the UK (5 %).

3.8 Angora

The Angora rabbit[9,21] (*Oryctolagus cuniculus*) is raised solely for its fine and soft hair, unlike other breeds which are produced for their meat and fur. The Angora rabbit is shown in Fig. 3.13. China is the principal producer and in that country the rabbits are farmed on a highly intensive small-scale factory farm system by individual farmers. Substantial quantities are also produced in France and smaller quantities in Eastern Europe and South America.

3.8.1 Fibre characteristics

The Angora rabbit produces three kinds of hair:

Guide hairs	100 to 110 mm long; they guide and cover the growth of the other hairs.
Guard hairs	80 mm long. These have rough points that lock together, lie over the down and seal it off.

3.13 Angora rabbit reproduced from Pier Giuseppe Alvigini, *The Fibres Nearest the Sky*, Mondadori Editore, Verona, by kind permission of Mr Pier Alvigini at Alvigini S.A.S. 13900 Biella, Via Dante, 12 Casella Postale 430, Italy.

Down 60 mm long. The diameter of 14 μm makes down one of the finest animal fibres used in textiles.

Some essential details about Angora rabbit hair are given in Table 3.11. The down fibres are very smooth, with few cuticle scales, and are depicted in Fig. 3.14. The Angora rabbit produces hairs of several colours but the strain bred for textile fibres is an albino strain that produces white fibres only. Coloured Angora rabbits are bred in India and their hair is used to produce artisanal fabrics. The hairs are all medullated (hollow) which decreases their weight by nearly 20 % when compared to wool and also increases their insulating properties.

3.8.2 Fibre production and manufacture

Partly because rabbit hair is produced on small-scale farms, actual production figures are difficult to establish, but it is estimated the world production is around 3000 tonnes. France may produce around 1000 tonnes. There are three strains of the Angora rabbit, the Chinese, the French and the German. The Chinese strain supplies 95 % of Chinese and South American production.

The rabbits are generally shorn every three months before the hair starts falling which causes felting. Females, as long as they are not in gestation or lactation, produce 25 % to 30 % more hair than males. Rabbit hair is a delicate fibre and care must be taken when preparing it for sale. The fibres themselves are very clean, as the rabbits produce only 2 % of their fibre weight in skin excretions, and also because rabbits clean their own fur. Nonetheless, it is necessary to remove dust and vegetable matter from the fleeces before the fibres are sorted and this is done by grooming. After the removal of this extraneous matter the hairs do not need scouring before carding.

After grooming, fleeces or part fleeces with lower quality fibre are removed and the remainder sorted into 4 grades:

Grade 1 Clean, free of felting, over 6 cm long (70 % of the coat).
Grade 2 Clean, free of felting, under 6 cm but over 3 cm (15 % of the coat).
Grade 3 Clean, felted, second cut.
Grade 4 All dirty, discoloured fibre.

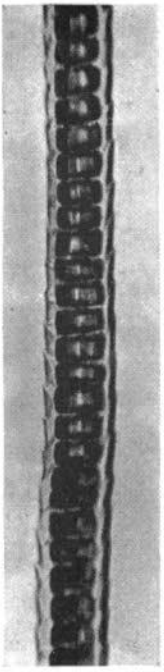
Clean hair is essential to Angora hair production because dirty hair fetches only about 15 % of the price of first quality hair, which is cheaper than the hair from ordinary breeds.

Yields of down hair show considerable variation, from 250 g to 1350 g per year, although the latter weight was produced from a genetically selected animal in an experimental station in Germany. More common commercial yields vary between 420 g and 820 g a year in China and up to 1000 g a year in France and 1200 g a year in Germany. Rearing conditions, especially the

Table 3.11 Whole mount, cross-section and scale pattern of rabbit

Animal	Whole mount			Cross-section				Scale pattern		
	Profile	Medulla	Pigment distribution	Contour	Medulla	Cuticle	Pigment distribution	Base	Mid-length	Tip
Rabbit *Oryctolagus cuniculus*	*Fine* Fairly regular diameter, scale margins prominent	Ladder	Often on cortical bridges	Oval to rectangular	Wide, mostly uni-serial, some multi-serial	Thin	None to very dense	Irregular petal, *or* shallow irregular waved mosaic, smooth; near margins	Single or double chevron *or* Double chevron → interrupted streaked wave	Single chevron

Source: *Guide to the Identification of Animal Fibres*, H.M. Appleyard, by kind permission of BTTG, Wira House, West Park Ring Road, Leeds, LS16 6QL.



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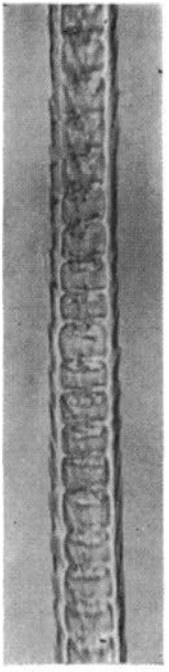

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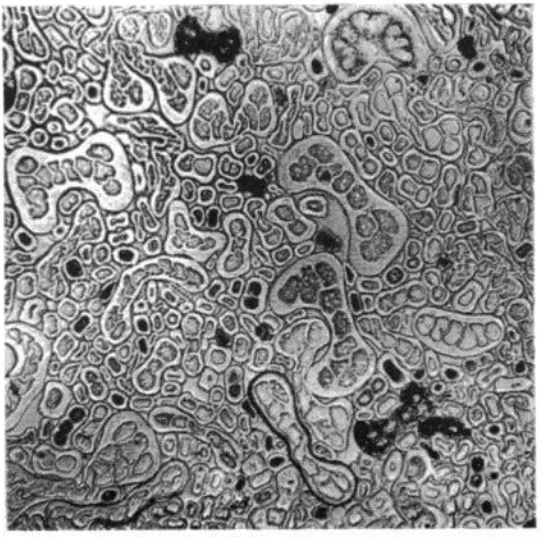

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3.14 Rabbit fibres: (a) rabbit, fine fibre, whole mount showing 'air'-filled medulla, 400×; (b) rabbit, fine fibre, whole mount showing medulla filled with mountant, 400×; (c) rabbit, cross-sections of light fawn matchings, 200×. Reproduced from H.M. Appleyard. *A Guide the Identification of Animal Fibres* by kind permission of BTTG, Wira House, West Park Ring Road, Leeds LS16 6QL.

quality and quantity of food supplied, are major factors affecting yield. Raising Angora rabbits for their hair is labour-intensive and highly skilled work if the results are to be viable.

The fibre is very fine and very smooth. This makes it difficult to spin, with a constant risk of fibre shedding, but the lack of fibre-to-fibre friction is overcome in spinning by the twist imparted and the length of the fibre. Hairs from other breeds, which are shorter, cannot be spun into yarns of adequate levelness and strength. The fibre is usually blended with other fibres such as fine wools, often with a small proportion of nylon.

There are two principal types of hair; the 'French' and the 'German' type. The former contains guard hairs which do not dye, is longer and 'spikier' than the German type and can be used to produce a fine brushed appearance. The German type is finer in diameter and produces a softer yarn.

3.8.3 Prices and distribution

Both production and prices have shown extraordinary variations, beyond those justified by the three to five year fashion cycle. For example, from 1976 to 1978 prices doubled from US$13/kg to US$28/kg. These prices further increased, obviously as the result of demand exceeding supply, and during the next ten years reached US$45 to 50/kg. In 1988 the situation was reversed, production exceeded demand and the price fell back to US$20/kg. In that year production was estimated at some 9000 tonnes. In 1992 the price increased to US$30/kg.

In 2000, with a world production of around 3000 tonnes, and in the first quarter of 2001 the price averaged at US$16/kg,[6] which is below French production prices, with the result that French production is in crisis, despite French Angora's traditional premium of approximately 50 % over world prices.

3.8.4 End-uses

Rabbit hair is principally used for knitting, usually blended with other fibres, mainly wool, and usually spun on the woollen system. Its annual consumption is greatly influenced by fashion and fluctates between 5000 and 6000 tonnes.[6]

3.9 Yak fibre

The yak (*Bos* (*poephagus*) *grunniens*) is a bovine. It is a shaggy, massive-looking animal – the adult weighs about 350 kg. It is depicted in Fig. 3.15. Yaks live on the high slopes of the Himalayas from the snow line down to approximately 1000 m below it and sometimes inhabit land up to 6000 m. There are both wild and domestic yaks.

3.15 Yak reproduced from Pier Giuseppe Alvigini, *The Fibres Nearest the Sky*, Mondadori Editore, Verona, by kind permission of Mr Pier Alvigini at Alvigini S.A.S. 13900 Biella Via Dante, 12 Casella Postale 430, Italy.

Domesticated yaks are beasts of burden and produce meat, milk, leather and fibres for the local population, who may live at altitudes up to 4000 m, and higher in certain cases. Crosses between yaks and Himalayan cattle living below the yaks' altitudes are bred to operate lower in the mountains but above the possibilities of wheeled transport. Yaks have developed the outer guard hair and fine down of other species living under similar cold conditions.

3.9.1 Production, fibre characteristics and distribution

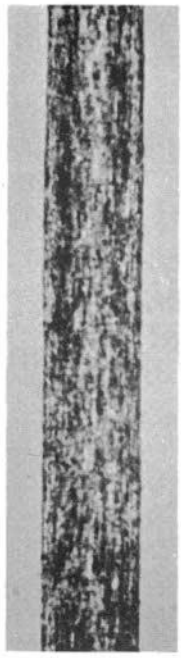
Each yak produces about 100 g of down fibre per year and although no recent figures of total production are available, about 1000 tonnes per year would seem to be a reasonable estimate. China (Qinhai, Sichuan and Gansu provinces) is the major producer of the down hair that is commercialised.

The down is harvested by combing or pulling the fibres during the spring moulting period. The calves' down fibres are 40 mm to 50 mm long and between 15 and 17 μm in diameter, placing them in a similar class to the very fine and soft category of the guanaco, vicuña and musk ox. Table 3.12 gives information about the fibres. The diameter of the adults' hair is coarser, between 18 μm and 20 μm and their length is from 30 mm to 35 mm, as is shown in Fig. 3.16. The fine hair has no medulla but the coarser guard hair is medullated, sometimes irregularly. Yak hair is white (that, as with all animal fibres is the most valuable because it can be dyed to any shade), fawn, dark grey and dark brown.

Table 3.12 Whole mount, cross-section and scale pattern of yak

Whole mount			Cross-section				Scale pattern		
Profile	Medulla	Pigment distribution	Contour	Medulla	Cuticle	Pigment distribution	Base	Mid-length	Tip
Fine									
Fairly regular diameter, scale margins slightly prominent	None	None to very dense	Oval to circular	None	Thin	None to very dense, even	Waved mosaic, smooth near margins		Waved crenate, near margins
Coarse									
Regular diameter, scale margins protrude slightly	Narrow interrupted or continuous	None to very dense	Oval to circular	None or narrow	Fairly thick	None to very dense, even	Waved crenate, near to close margins		

Source: *Guide to the Identification of Animal Fibres*, H.M. Appleyard, by kind permission of BTTG, Wira House, West Park Ring Road, Leeds, LS16 6QL.



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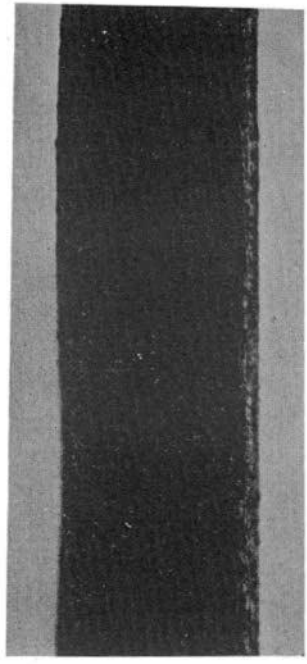

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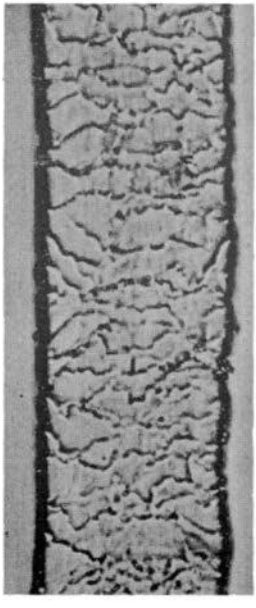

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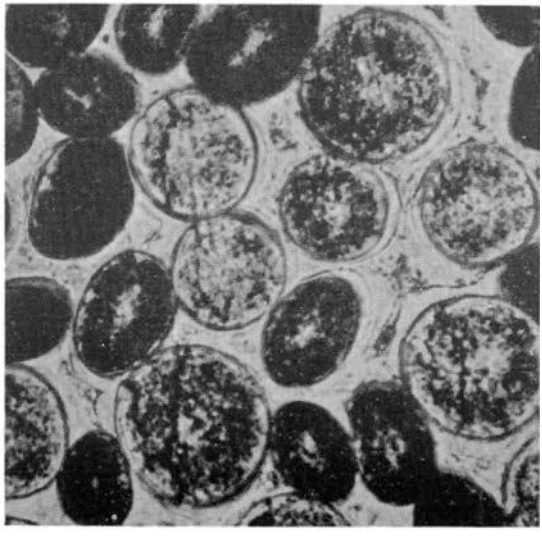


e

3.16 Yak fibres: (a) fine fibre, whole mount, 200×; (b) coarse fibre, whole mount, 200×; (c) fine fibre, cast of scale pattern, 400×; (d) coarse fibre, cast of scale pattern, 400×; (e) cross-sections, 200×. Reproduced from H.M. Appleyard. *A Guide to the Identification of Animal Fibres* by kind permission of BTTG, Wira House, West Park Ring Road, Leeds LS16 6QL.

When gathered by the farmers, the fibre, which has not yet been dehaired, is packed into sacks and sent to warehouses where it is hand-sorted for colour, and as much as possible of the outer hair removed. Sorters handle about 10 kg per day. The proportions of the colours produced are approximately 10 % white, 20 % fawn, 10 % dark grey (blue) and 60 % brown.

3.9.2 End-uses and consumers

Although what must be a substantial part of total yak fibre production is consumed on, or very near, the place of production by farmers or within their local villages, the quantities that are distributed and consumed in this way are not known. That part of production destined to be commercialised is machine spun, made into knitwear and exported to the usual developed countries, mostly through Chinese knitting companies. Some yak hair is exported and becomes available through merchants in the world's major textile centres.

3.10 Musk ox fibre

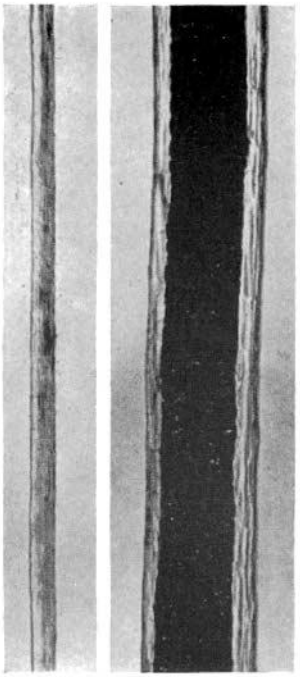
Musk ox (*Ovibos moschatus*) are large animals, weighing between 250 and 400 kg and varying between 1 and 2 m high; they live in the extreme north of Canada and Greenland. See Fig. 3.17. Their full name is the bearded Canadian musk ox and they are members of the Bovidae family, as are cattle and goats. They were hunted almost to extinction and were saved only by being declared a protected species in 1917. Musk ox are wild, but there are some protected herds. Present population is estimated at 160 000.[22]

3.17 Musk ox. By kind permission of Ms Nancy Bender, The Musk Ox Company, 633 Fish Hatchery Road, Hamilton, Montana 59840 USA.

Table 3.13 Whole mount, cross-section and scale pattern of musk ox

Whole mount			Cross-section				Scale pattern		
Profile	Medulla	Pigment distribution	Contour	Medulla	Cuticle	Pigment distribution	Base	Mid-length	Tip
Fine									
Fairly regular diameter, fairly smooth	None	Uneven, some large aggregates	Circular to oval	None	Thin	Bi-lateral	Irregular waved mosaic, smooth; distant margins		
Coarse									
Fairly regular diameter, fairly smooth	Wide lattice	Some very dense, often in large aggregates dense	Flattened oval	Concentric	Thin	Some very dense, often most dense near medulla	Irregular waved mosaic, smooth; near margins		

Source: *Guide to the Identification of Animal Fibres*, H.M. Appleyard, by kind permission of BTTG, Wira House, West Park Ring Road, Leeds, LS16 6QL.



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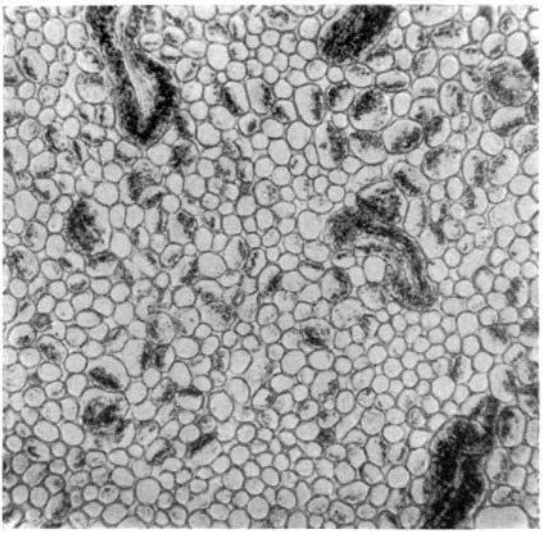

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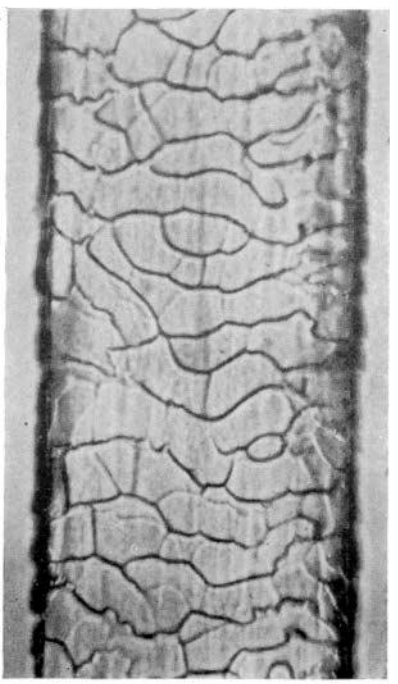

e

3.18 Musk ox fibres: (a) fine fibre, whole mount, 200×; (b) coarse fibre, whole mount, 200×; (c) cross-sections, 200×; (d) fine fibre, cast of scale pattern, 400×; (e) coarse fibre, cast of scale pattern, 400×. Reproduced from H.M. Appleyard. *A Guide to the Identification of Animal Fibres* by kind permission of BTTG, Wira House, West Park Ring Road, Leeds LS16 6QL.

3.10.1 Production, fibre characteristics and distribution

Musk ox have the two types of hair that are usual in mammals living in such cold conditions, fine under-hair or down, and coarse outer guard hairs; Table 3.13 gives relevant information. The native name for the down is qiviut, or quiviuk.[9,22]

During the spring moult the musk ox loses down hair which falls off in large slabs and is collected. Each animal produces around 1.5 kg of down of which perhaps 60 % is recoverable by conventional dehairing techniques. Higharctic employ a process which recovers nearly 100 % of the down.[23] The fibres are unmedullated, with an average diameter of 12.5 µm and a range of 17–22 µm. The guard hair diameter is 30 µm or over. Figure 3.18 shows musk ox fibres. This places quiviut amongst the finest hair fibres because it is comparatively smooth with low crimp. Length is 40–70 mm. Scoured and dehaired fibre is light brown to chocolate brown in colour.[22]

The fibres need to be dehaired before being machine spun and dyed, if required. The dehairing is done manually by the Inuit or by the Forte Cashmere Company, Inc in Rhode Island, USA, which receives the fibres in batches of 500 or 1000 kg from the Ooming Mak Musk Ox Production Corporation in Anchorage, Alaska.[7] Alternatively, the dehairing is carried out by Higharctic.

The down is rather short to be spun on the worsted system and needs to be blended with another longer fibre such as baby alpaca;[16] if it is 100 % qiviut it is usually woollen spun. Annual qiviut production is estimated at approximately 3000 kg[16] which is small, even by 'luxury fibre' standards and similar to the production of guanaco at around 5000 kg.

3.10.2 End-uses and distribution

The development of the musk ox fibre market, small as it is, was due to the desire to encourage the economic development of the isolated communities of the far north. Once dehaired locally or at the Forte Cashmere Company and spun, and apart from a small quantity used for blending with other fibres, the qiviut is sent back to the far north and hand-knitted by Eskimo women, working at home. Most of the knitwear produced is sold to tourists and to a few high-class boutiques.[23]

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