Differentiating Fine Hairs from Wild and Domestic Species: Investigations of Shatoosh, Yangir, and Cashmere Fibers

CLAUDIO TONIN, MICHELA BIANCHETTO, AND CLAUDIA VINEIS

Consiglio Nazionale delle Ricerche, Istituto per lo Studio delle Macromolecole, Biella, Italy

MARCO FESTA BIANCHET

Département de Biologie, Université de Sherbrooke, Sherbrooke, Québec J1K 2R1, Canada

ABSTRACT

The fine undercoat fibers removed from wild goats hunted for meat and trophy, principally belonging to subspecies of *Capra ibex*, are used as an alternative to Shatoosh, the hair of the endangered Tibetan antelope (*Pantholops hodgsonii*). Although currently legal, the large-scale use of these fibers (known as "Yangir"), and hybridization of ibex with domestic goats to improve fiber fineness and yield, would severely threaten the conservation of wild ibex. A SEM investigation shows morphological differences in the cuticle cell patterns of fine fibers from the domestic Cashmere goat, the wild Yangir goat, and the Tibetan antelope. A study of the DSC traces reveals differences in the enthalpy of denaturation of the crystallites. This information enables identification of these fibers, including those from lots submitted to dehairing processes, such as are commonly found in the animal fiber trade.

Fine, soft, warm fibers from the undercoat of several wild and domestic mammals of the genera *Capra, Bos, Camelus,* and *Lama* are primarily used by the fashion industry for manufacturing high-quality, luxury textiles. Among these "speciality fibers," Cashmere, the fine down fibers produced by a domestic goat indigenous to Asia and known as the Cashmere goat (*Capra hircus laniger*), is currently the most known and requested by higher-end customers; thus, cashmere garments are status symbols of the fashion industry.

Shatoosh, made from the hair of the Tibetan antelope (*Pantholops hodgsonii*), called "Chiru" in Tibetan, probably represents an extreme aspect in the value of premium fibers. Shatoosh means "king of wools" in Urdu [3], is one of the world's finest hairs, and is used to manufacture the famous "ring shawls." The most common way to obtain shatoosh is to kill wild Tibetan antelopes, and at least five Chirus must be killed and skinned to produce a single shawl. A traditional market for Shatoosh shawls has existed for centuries in northern India. In recent years, however, rising demand from the Western market, together with easier access to Chiru habitat by poachers in motorized vehicles [14], has caused a drastic decline of this species, which is now to the point of extinction. According to expert estimates, fewer than 75,000 Tibetan antelopes remain in the wild, and as many as 20,000 may be killed this year (2001) by poachers [8]. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) classifies the Tibetan antelope in Appendix I, its highest level of protection, which bans all international trade on this species. Internal trade in Shatoosh and other Tibetan antelope products is also illegal in many countries, and recently, the Shatoosh issue has gained considerable visibility in the media. Thus, environmental organizations, law enforcement authorities, and fashion industry leaders are working to reduce the demand for Shatoosh and to publicize alternatives. Potential alternative textile fibers include cashmere and domestic yak hair, but also hair from wild animals, especially wild goats, which are slaughtered for this purpose.

The wild species most commonly exploited for textile fibers is probably the Asiatic ibex (*Capra ibex sibirica*), also called the "Yangir" mountain goat. Although named after Siberia, the Asiatic ibex lives in mountainous areas from India to Mongolia; these animals are widely distributed and are hunted by local populations, as well as foreign trophy hunters [13]. Recently, several lots of dehaired wild goat fibers have been offered for sale in the Western markets, under the name of "Yangir" or "Wild Cashmere," allegedly removed from animals killed for meat. Experts believe that to obtain 1000 kg of these dehaired fibers, it would be necessary to kill 15,000 animals. These lots contain mostly hair of the Asiatic ibex, possibly blended with small amounts of hair from other species of wild goats that are impossible to identify, because the taxonomic classification of Caprinae is still controversial and, moreover, different from the trophy-type classification used by hunters [15]. The "official" taxonomy currently lists four wild *Capra* species (*aegagrus, ibex, falconeri,* and *cylindricornis*), but many scientists are of the opinion that there may be three or more distinct species of ibex. The only CITES-listed species is the markhor (*Capra falconeri*), but apart from any other considerations, it is clear that no species of wild goat could sustain the level of harvest necessary to meet the needs of industrial uses of their hair, if the demand for Wild Cashmere increases in the fashion world. Moreover, hybridization with domestic goats in order to improve fiber fineness and yield would involve a risk of genetic pollution of the wild species [22]. It is therefore important to be able to identify the origin of different kinds of hair sold in western markets.

In a recent paper, Rollins and Hall [11] described criteria for distinguishing hairs of the endangered Tibetan antelope from ibex hair, using a light microscope and a scanning electron microscope (SEM). Although differences in the features of the fine fibers emerged, the best differentiation was accomplished on the basis of the histological morphology differences found in the guard hair examined under the SEM, because Tibetan antelope guard fibers show distinctive benzene-ring surface scale markings.

In this paper, we describe the morphological and thermal properties of fine fibers from the domestic Cashmere goat, the Yangir wild goat, and the endangered Tibetan antelope, with the aim of providing a means for identifying the origin of the fibers also from lots submitted to dehairing processes, such as those found in the animal fiber trade.

Experimental

Authentic samples of Yangir (Wild Cashmere) and cashmere fibers with comparable fineness were kindly supplied by Italian dealers and manufacturers. Tibetan antelope fibers were withdrawn from the Scientific Archives of the Italian National Research Council. The samples were first cleaned with petroleum-ether for 2 hours in a Soxlet, then dried and conditioned in standard atmosphere at 20°C and 65% RH for 24 hours. Fiber fineness was measured with a BSC optical fiber diameter analyzer (OFDA) on about 10,000 fibers per sample.

The microscopic investigation was performed with a Cambridge Stereoscan 240 SEM at an acceleration voltage of 15 kV and a 12–15 mm working distance. The fibers were mounted on aluminum specimen stubs with double-sided adhesive tape and sputter-coated with a 20 nm thick gold layer in rarefied argon, using an Emitech K 550 sputter coater with a current of 20 mA for 180 seconds.

The differential scanning calorimeter (DSC) analysis was performed with a mettler Toledo DSC 821, flushing the calorimeter cell with 150 ml/min of nitrogen. The temperature program was set in the range from 30 to 300°C at a heating rate of 10°C/min, and the instrument was calibrated with indium as a standard. The data were collected on a computer using the Mettler Toledo Star System. About 3 mg of fibers were used in each test, cut into a few thousand snippets 1 mm long by a hand microtome to optimize the heat transmission to the crucible. All tests were repeated three times, and the repeatability of the DSC traces was confirmed.

Results and Discussion

The mean fiber diameters (MFD) of the samples, determined by OFDA for 10,000 fibers per species, are shown in Table I, together with the size distribution parameters. The coarse hair content, as defined by ASTM D 2816 [1], was very low: only 0.1% of the fibers were thicker than 30 μm, likely because of an accurate preliminary dehairing treatment to which the fiber lots were subjected. Semi-manufactured textiles and finished garments at this stage of processing cannot be analyzed on the basis of the guard hair morphology as described by Rollins and Hall [11].

TABLE I. Mean fiber diameter (MFD), size distribution parameters, and coarse hair content of Shatoosh, Yangir, and Cashmere fiber samples.

	Mean fiber diameter (MFD), μm	Standard deviation (S), μm	Coefficient of variation (CV), %	Coarse hair content, %
Shatoosh	11.5	2.3	20.1	0.1
Yangir	13.6	3.1	22.6	0.1
Cashmere	13.9	2.8	20.2	0.1

Figure 1 shows a significant overlap between the size distribution of the fiber diameters from Yangir and Cashmere. The results for the Shatoosh fiber sample agreed with the data available from the technical literature [7, 10, 11].

The SEM investigation of the fiber surfaces showed clear species-specific cuticle scale patterns: the surface morphology of the cuticle cells reflected variations in length, shape, orientation, and frequency.

The cuticle scale patterns of Shatoosh fibers were very distinctive: the cuticle cells appeared strongly oriented

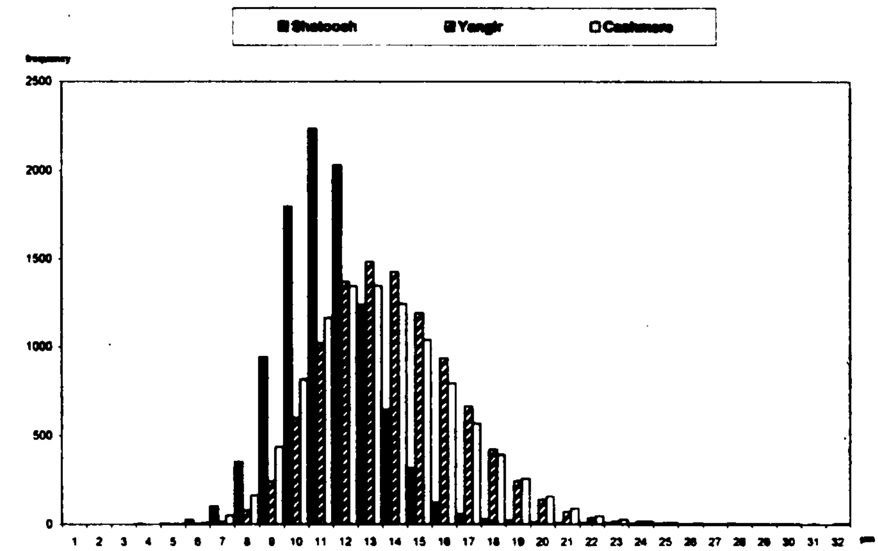

FIGURE 1. Size distribution of shatoosh, yangir, and cashmere fibers.

and elongated in the direction of the fiber axis (Figure 2); their lengths, as well as their thicknesses at the distal edge, were pronounced relative to the fiber diameter. According to Langley [7], five to six scales per 100 μm length of fiber were found; as a result, all these morphological characteristics indicated many changes in the apparent fiber diameter along the fiber axis. Cashmere fibers showed the well known surface morphology (Figure 3) extensively described in the technical literature [4, 6, 9, 18, 20]; they were even in diameter, cylindrical, and had cuticle cells with relatively distant and smooth margins, often so wide that they appeared to entirely envelop the finer fibers.

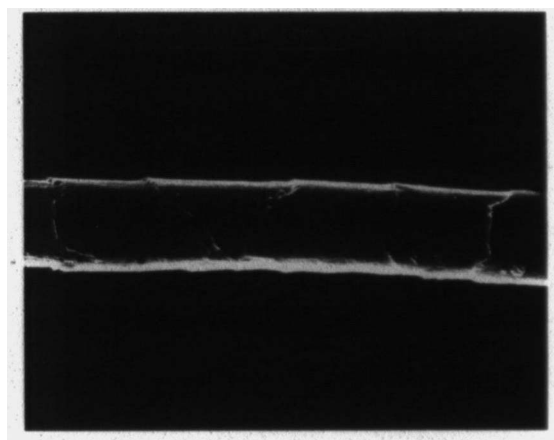

FIGURE 3. Cashmere fiber: 1940×.

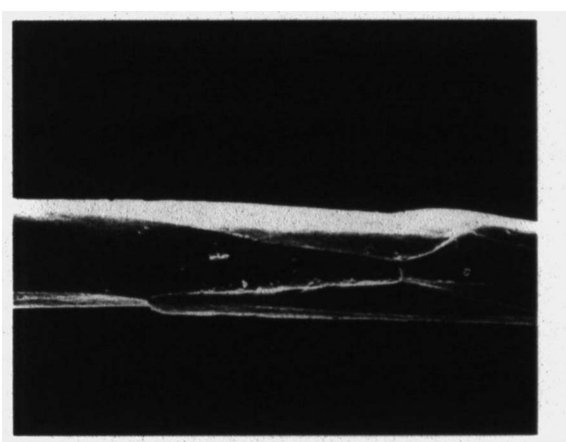

FIGURE 2. Shatoosh fiber: 1940×.

Yangir fibers showed intermediate cuticle scale patterns (Figure 4a), although there was considerable morphological variability between the images of the fiber surfaces (Figure 4b). The scale density of Yangir fibers ranged from 5–6 to 18–20 scales per 100 μm fiber length. Cuticle cell shape varied from a Cashmere-like arrangement to a strongly oriented and elongated shape in the direction of the fiber axis, somewhat similar to Shatoosh. The most typical morphological properties revealed by SEM, however, were the thickness of the scale edge, which was higher than that of Cashmere and was associated with changes in the apparent fiber diameter along the fiber axis, a morphology never found with Cashmere.

Many authors have described relationships between fiber diameter and scale pattern type [19], and between the rate of growth in fiber length and the distance between scale ridges [12]. Comparisons of wild and do-

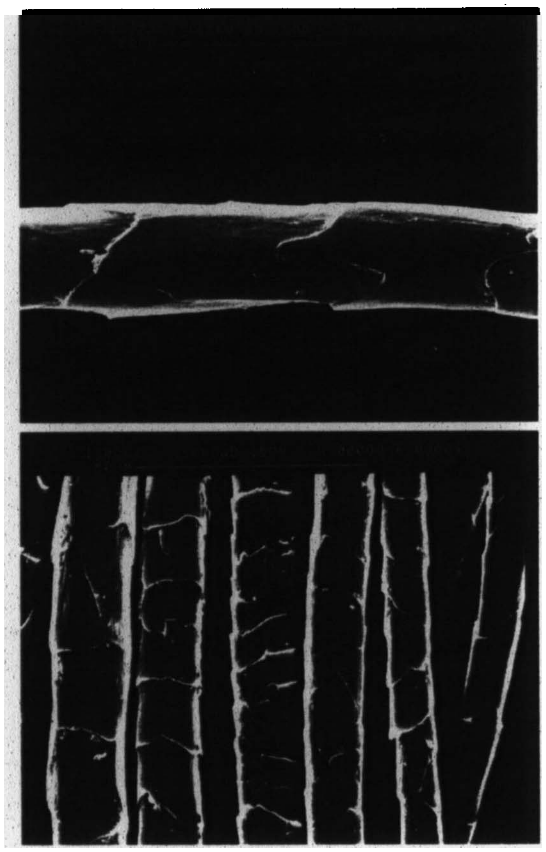

FIGURE 4. Yangir or Wild Cashmere fibers: (a, top) 1980×, and (b, bottom) 1000×.

mestic species appear to suggest a wider fiber diameter for domestic animals, associated with a less elongated shape of the cuticle scale patterns in the direction of the fiber axis, indicating a lower hair growth rate. These differences in hair morphology could arise because nutritional stresses and exposure to thermal excursions may lead to finer hair and a higher growth rate of the undercoat in wild than in domestic animals. Investigation of the thermal denaturation performance of Shatoosh, Cashmere, and Yangir raw fibers, never submitted to previous thermal treatments, revealed appreciable differences in the DSC traces in the temperature range 230–250°C (Figure 5): Yangir displayed a well balanced, characteristic endothermic doublet, with temperature peaks at 233 and 241°C; Shatoosh showed a bimodal trace with a less pronounced first endotherm and temperature peaks that shifted at 234 and 246°C; Cashmere showed a trace with one endotherm peaking at 241°C and a shoulder on the low temperature side. Also, the peak widths and, as a consequence, the relevant areas and associated enthalpies differed significantly [17].

DSC studies on a wide variety of keratin materials have been conducted by researchers in wool science to characterize the composite structure of wool and other animal hairs by investigating the thermal performance of their main morphological components. The presence of two endothermic peaks in the DSC traces of some keratin fibers in the temperature range 230–255°C in the dry state was mainly explained by two principal theories: the former attributed the doublet to differences in the ther-

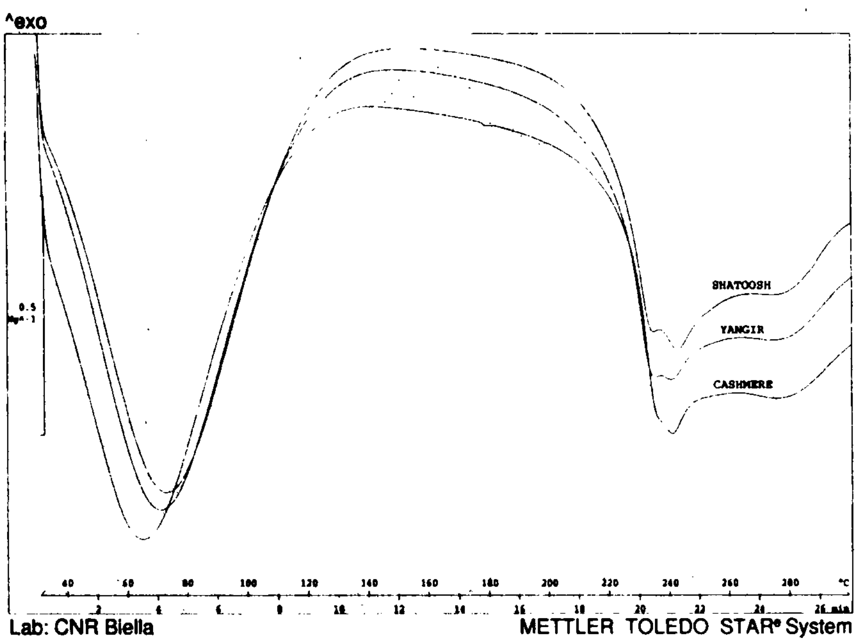

FIGURE 5. DSC traces of Shatoosh, Yangir, and Cashmere fibers.

mal denaturation of the α-form crystallites with respect to the degradation of other histological components [2, 16]; the latter explained the bimodal trace with differences in the transition performances of the α-helical material contained in the *ortho-* and *para-*cortical cells [5, 21].

Clearly, further and more detailed investigations of the histological structure of these fibers are required to explain the details of their thermal behavior. We suggest, however, that the differences displayed by the DSC traces provide a useful hint for fiber identification purposes.

Conclusions

Detecting visible differences in the physical properties of the fine undercoat hair of wild and domestic species provides a way of identifying the species of origin of different fibers available for the textile industry. Some of those fibers may originate from protected or potentially endangered wild species.

Investigation of the average and frequency distribution of fiber diameters and of their surface morphology and thermal degradation performance permits the identification of Shatoosh, Yangir, and Cashmere fibers, even from lots of materials previously subjected to dehairing processes.

Literature Cited

1. American Society for Testing and Materials, Standard Test Method for Cashmere Coarse-Hair Content in Cashmere, Test Method D 2816-95, Annual Book of ASTM Standards, Vol. 07.01, West Conshohocken, PA, 1999.
2. Cao, J., Origin of the Bimodal Melting Endotherm of α-Form Crystallites in Wool Keratin, *J. Appl. Polym. Sci.* **63,** 411–415 (1997).
3. CNN Italy, www.cnnitalia.it/1999/STILE/11/04/sciarpa.tibetana, Nov. 15, 1999.
4. Dobb, M. G., Johnston, F. R., Nott, J. A., Oster, L., Sikorski, J., and Simpson, W. S., Morphology of the Cuticle Layer in Wool Fibers and Other Animal Fibers, *J. Textile Inst.* **52,** 153–170 (1961).
5. Huson, M. G., Church, J. S., Heintze, G. N., and Pate, M., Spectroscopy, Microscopy and Thermal Analysis of the Bi-Modal Melting of Merino Wool, in "Proc. 10th Int. Wool Text. Res. Conf. Aachen" (D), Nov. 26–Dec. 1, 2000, Vol. ST-5, pp. 1–10.
6. Langley, K. D., and Kennedy, T. A., Jr., The Identification of Speciality Fibers, *Textile Res. J.* **51,** 703–709 (1981).
7. Langley, K. D., Shatoosh Fibers, *EFFN News* (2), (1997).
8. Lowe, J., Saving the Chiru, Tibetan Plateau Project, *Earth Island J.* **15,** Vol. 1, (2000).
9. Phan, K. H., "Electron Microscopy and the Characterization of Keratin Fibers," Universidade do Minho, Guimaraes, Portugal, 1991, pp. 53–58.
10. Phan, K. H., Wortmann, G., and Wortmann, F.-J., Microscopic Characteristics of Shatoosh and its Differentiation from Cashmere/Pashmina, in "Proc. 10th Int. Wool Text. Res. Conf. Aachen" (D), Nov. 26–Dec. 1, 2000, Vol. SF-2, pp. 1–16.
11. Rollins, C. K., and Hall, D. M., Using Light and Scanning Electron Microscopic Methods to Differentiate Ibex Goat and Tibetan Antelope Fibers, *Textile Res.* **69,** 856–860 (1999).
12. Rougeot, J., in "Biology of the Skin and Hair Growth, A. G. Lyne and B. F. Short, Eds., Angus & Robertson, Sydney, 1965, pp. 625–640.
13. Schaller, G. B., "Mountain Monarchs: Wild Sheep and Goats of the Himalaya," University of Chicago Press, IL, 1977.
14. Schaller, G. B., Wildlife of the Tibetan Steppe, University of Chicago Press, IL, 1998.
15. Shackleton, D. M., Ed., and the IUCN/SSC Caprinae Specialist Group, Wild Sheep and Goats and Their Relatives, Status Survey and Conservation Action Plan for Caprinae, IUCN Switzerland and Cambrige, Gland, U.K., 1997.
16. Spei, M., and Holzem, R., Thermoanalytical Investigations of Extended and Annealed Keratins, *Colloid Polym. Sci.* **265,** 965–970 (1987).
17. Spei, M., Thermoanalytical Methods and Their Meaningfulness in Keratin Research, *Melliand Textilber.* **11,** 902–904 (1990).
18. Wildman, A. B., "The Microscopy of Animal Fibers," Wool Ind. Res. Assoc., Leeds, U.K., 1954, pp. 106–112.
19. Woods, J. L., and Orwin, D. F. G., The Cytology of Cuticle Scale Pattern Formation in the Wool Follicle, *J. Ultrastructure Res.* **80,** 230–242 (1982).
20. Wortmann, F.-J., and Arns, W., Quantitative Fiber Mixture Analysis by Scanning Electron Microscopy, *Textile Res. J.* **56,** 442–446 (1986).
21. Wortmann, F.-J., and Deutz, H., Thermal Analysis of *Ortho-* and *Para-*Cortical Cells Isolated from Wool Fibers, *J. Appl. Polym. Sci.* **68,** 1991–1995 (1998).
22. Yerxat, M., and Yalejean, M., Application of Wild Goats in Cashmere Breeding, *Small Ruminants Res.* **15,** 287–291 (1995).

Manuscript received October 12, 2001; accepted January 23, 2002.