Identification of goods made of valuable wool sorts with the use of remote technologies

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Abstract. Animal hair is a traditional valuable raw material for the textile industry. However, its cost varies over a wide range and depends on the animal species, certain qualitative characteristics. There are cases of wool products falsification according to their fibrous structure in the whole world. The scientific world is undertaking studies aimed at improving the existing and creating new methods of identification of wool, including those with the use of information technologies. Results of determining fibrous structure of different products made of animal hair in mixtures with sheep wool are presented in the article; these results demonstrate the fact of falsification of textile products on the Russian market. The problems of identifying are considered in the article and the scheme of using remote technologies for purposes of improving expert practice is suggested.

1. Introduction

When producing textile products, together with sheep wool, hair covering of other more rare animals is used: cashmere (Capra hircus), yak (Bos grunniens), camel (Camelus ferus), alpaca (Vicugna pacos), Angora rabbit (Oryctolagus cuniculus). The cost of products made of these kinds of textile raw material is higher; that is the reason for their falsification. The cases of falsification of textile products made of valuable animal hair are confirmed in different regions of the world [1] and that is the problem which brings down consumers' trust and damages the reputation of this branch in certain countries.

Identification of fiber structure of textile products made of valuable sorts of wool has certain difficulties in expert practice. Hair covering of animals of all species consists of keratin protein which makes it impossible to use standard chemical methods for quantitative identification of fine hairs of animals in blends with sheep wool because chemical properties, including solubility of these fibres, are the same. Also, raw materials are exposed to a range of mechanical and chemical impacts in the process of making a textile product, which may add additional difficulties to the process of identification because hair structure changes.

Lately, scientific studies aimed at improving the existing and creating alternative methods of identification of special fibers in blends with wool have been actively undertaken.
The employees of Shanghai Textile Research and Development Institute, together with Mechanical Engineering College of Donghua University (China) [2] suggest using ultrasound in the traditional methodology for quantitative determination of mass fraction in wool fiber in blends with other fibers. Ultrasonic dissolution allows reducing the concentration of alkali and the time of dissolution without decreasing the accuracy of results.

D. Molloy and M. Naftaly from the National Physical Laboratory of Teddington (Great Britain) [3] have stated the possibility of using terahertz spectroscopy for identifying wool of different animals and struggling with textile falsification.

Differential scanning calorimetry is suggested by the authors of [4] as an alternative qualitative method of identification of various fibers of animal origin.

The method of quantitative estimation of a cashmere and sheep wool blend on the basis of analysis of mitochondrial DNA is described in the [5] work. M. Tang, W. Zhang and H. Zhou have selected two sets of primers and probes of polymerase chain reaction which can specifically respond to goat and sheep genes. Cashmere was used to test the method which was obtained from goats of different age, from various geographic locations, raw and processed, including cashmere exposed to stretching. There was no significant difference in the results which allowed the authors to recommend using the method for checking the quality of cashmere production on the world market.

A group of authors from the Institute of Macromolecular Research (Biella, Italy) have suggested the method [6] based on ultraperformance liquid chromatography in combination with electro spray mass-spectrometry (UPLC/ESI-MS) for identification and quantitative determination of wool, cashmere fibers and yak underwool. The method was tested on many well-known and unknown blends of wool/ cashmere/ yak at different stages of production and with different processing (colored, depigmented, bleached, ready-made goods, raw materials).

One of the directions for developing the methods of fiber identification is automatic identification on the basis of digital processing of images obtained with the help of microscopy.

Efficient and accurate extraction of representative characteristics has great significance for identification of animal fiber. In the work [7], two different strategies are developed. In the first method, obvious functions are being extracted by means of image processing. However, the second method uses not obvious features with an uncontrolled artificial neural network.

The authors of the article [8] have used convolution neural networks for solving the problems related to the difficulty of identifying cashmere and wool which is suggested to be carried out in two stages. The authors have demonstrated that not only texture is the key element of cashmere and wool identification but the picture color is also important.

Two-level identification is also applied by Liu W.-L. In the article [9], he suggested a method based on a local binary pattern (LBP) for identification of wool and cashmere fibers. Micrographic images of these fibers are transformed into collections of LBP codes. Then, the vectors which designate LBP codes histograms are applied for presentation of fibers images. Several methods based on LBP for extracting characteristics have been compared and the results show that a complete LBP is most accurate.

In the work by Shu-Yuan Shang, Ya-Xia Liu, Hai-Yan Yi and Yao-Wen Zhang [10] it is suggested to use computer automatic measuring of fibers diameter. The experiment was carried out in the Matlab7.0. modeling environment on the basis of analysis of images obtained after primary processing. The method is recommended by the authors for identifying sheep wool and cashmere and also differences between wool and stretch-wool exposed to stretching for increasing fiber fineness.

In the works [11, 12], it is demonstrated that using wavelet decomposition when analyzing microscopical shots of fibers with the aim of determining cashmere and ultrafine fibers of merino wool is advisable. In the work [11], the possibility of using wavelet decomposition when analyzing images of fiber texture, obtained with the help of electronic microscopy, has been demonstrated. Y. Zhong, K. Lu, J. Tian [12] have transferred microscopic images, made with a CCD camera, into projection curves. Experimental results have demonstrated that the suggested projection curves can be used as a mathematical replicate in automatic identification of cashmere and sheep wool.
Another tendency of development of fiber identification methods is the attempt to automate identification of fibers by means of combining the methods of chemical analysis with informational technologies.

In the article [13], results of studying the possibility of identification of two sorts of animal fibers – merino sheep wool and mohair – with the use of artificial neural networks are being specified. The authors have suggested two models: the first one includes processing of images with the help of a scale which consists of nine parameters, and the second one functions with the help of an uncontrolled artificial neural network which allows to automatically extracting characteristics. The second model is acknowledged by the authors as a more reliable one, though the first model can achieve the required accuracy.

The authors of the work [1] have presented a scheme of automatic identification of fine and cashmere fiber by means of the Vis/NIR spectroscopy method. The spectra, after preliminary processing, are taken as input data of a three-layer back propagation artificial neural network (BP-ANN). The network training was carried out on the basis of well-known fiber spectra. Multi-level representation of images, useful during their recognition, has been considered by the authors of the article [14].

The aim of this study is identification of fiber composition of products which contain valuable sorts of animal hair on the Russian market, by means of standard methods, and development of suggestions aimed at improving expert practice of identification of fiber composition of textile products with the use of remote technologies.

2. Materials and methods

Textile products made of blends of fine animal hair with sheep wool have been chosen as the objects of this study. These are products made of mohair, cashmere, camel hair, angora, both of Russian and foreign manufacture. In total, 25 sorts of textile products which are in free circulation on the territory of Russia have been analyzed. The products were purchased in retail trade network.

Determination of the fiber composition was carried out according to standard methods with the use of reference fibers. Mass fraction of protein fibers was determined by the chemical method according to GOST 4659 All-wool and Half-wool Fabrics and Yarns. The chemical testing methods, GOST 30387 Cloths and Knitted Goods. The methods of determining the sort and mass fraction of raw materials.

The microscopic analysis method was used in the work; the method was described in the Association of Textile Chemists and Colorists (AATCC) standard, TM20A [15], and also the materials of AATCC TM 20[16], ISO 17751 [17] standards.

2.1. Preparation of samples

If the sample, being studied, was yarn, then a part of no less than 2 meters long was separated from the skein. Then, in a random manner, 20 pieces, 5 cm long, were selected. 2.5 cm of yarn from each selected piece was cut into small parts, 0.5–1 mm in size. The fragmented yarn was placed into a bulb, several glass balls were added into it for convenient separating of fibers, and the yarn was covered with mineral oil. The fibers were thoroughly mixed by means of stirring up. A volume of 0.5 ml was taken from the prepared suspension with the help of a wide capillary. The fibers, distributed in the mineral oil with the refraction index of 1.515, were placed between preparation and cover glasses.

The samples of knitted goods were previously separated into compound threads.

2.2. Identification

The prepared products for microscopic examination were placed on the object table of an optical microscope Mikmed, fitted with a video eyepiece, and then they were examined with the 300x magnification. The examination of the product started from the upper left corner, gradually being shifted to the right. In each viewing field all fibers intersecting the center of the viewing field cross line were identified and measured.
After examining the product in a horizontal plane the position of the glass was shifted vertically by 2 mm and horizontal inspection was continued. The operations were repeated till the product was examined completely. 1000 fibers were analyzed for each sample.

Measuring the diameter of fibers was made with the help of program software, ScopePhoto. The viewing field image was captured by the video eyepiece. The researchers measured and identified diameters of all fibers in the viewing field, avoiding recurrences, and mean values were translated into µm. The image calibration measurement was carried out with the help of a stage micrometer.

2.3. Calculations
The mass fraction of fibers in the blend was determined according to the formula (1) which is true for fibers with circular cross section:

\[
X_R = \frac{N_R \cdot D_R^2 \cdot \pi \cdot S_R}{\sum (N \cdot D_R^2 \cdot \pi \cdot S)}
\]

where:
\( X_R \) – the mass fraction of R-type fiber, %;
\( N_R \) – the relative value of R-type fiber;
\( D_R \) – the mean diameter of R-type fiber; µm
\( S_R \) – the specific gravity of R-type fiber;
\( \sum (N \cdot D_R^2 \cdot \pi \cdot S) \) – the amount of all types of fibers in the blend

3. Results and discussion
3.1. The results of determining fiber composition of samples
Results of quantitative determining of mass fraction of wool fiber by means of a chemical method are presented in table 1. This method allowed determining the total content of protein fibers of wool and fine animal hair, and also of natural silk in yarn.

Falsification of wool was revealed in 11 samples out of 25, and that made 44%.

The results of quantitative determination of the most valuable component of the fiber blend (angora, fine camel hair) according to the AATCC 20A methods are presented in table 2.

Among the five samples being studied (7–11) which contain angora, only sample 7 made in France conforms to the marking.

Among the samples from 17 to 20, camel hair was determined only in the sample from Mongolia (“Mongol Nekhmel” factory) in the quantity stated in the marking. Sample 20 contained only 5% of camel hair out of the 60% stated in the marking; no camel hair was determined in sample 19 while 15% of this fiber was stated in the marking.

Sample 18 is a typical case of deceiving consumers concerning the fiber composition of the product. There is a picture of a camel on the label – the only one of the existing images, while it is stated “wool 70%” in the marking. This sample doesn't contain camel hair and the content of sheep wool is significantly lower than it is stated in the marking.
Table 1. Results of determining mass fraction of protein fiber in the samples being studied.

| Sample number | Producer (country) | Fiber structure (acc. to marking), % | Factual mass fraction of protein fiber, % |
|---------------|--------------------|-------------------------------------|----------------------------------------|
| 1             | Italy              | 100% angora                         | 100.00                                 |
| 2             | France             | 70% angora; 30% wool                 | 100.00                                 |
| 3             | Turkey             | 70% angora; 30% acryl               | 39.05                                  |
| 4             | Turkey             | 70% angora; 30% acryl               | 49.09                                  |
| 5             | Russia             | 30% angora; 12% wool; 41% acryl; 17% caprone | 42.60                                 |
| 6             | Russia             | 30% angora; 70% acryl               | 33.93                                  |
| 7             | France             | 80% angora; 20% merino (sheep wool) | 100.00                                 |
| 8             | China              | 80% angora; 20% nylon               | 56.00                                  |
| 9             | Italy              | 70% angora; 10% merino (sheep wool); 20% polyamide | 63.00                                 |
| 10            | China              | 40% angora; 60% acryl               | 28.00                                  |
| 11            | China              | 35% angora; 40% merino (sheep wool); 15% nylon | 68.00                                 |
| 12            | Russia             | 15% mohair; 25% wool; 15% acryl     | 42.40                                  |
| 13            | Great Britain      | 50% mohair; 50% acryl               | 50.60                                  |
| 14            | Turkey             | 60% mohair; 24% acryl; 16% methanite | 45.20                                 |
| 15            | Italy              | 70% kid-mohair; 20% silk; 10% lurex | 90.60                                  |
| 16            | Finland            | 80% kid-mohair; 20% polyamide       | 81.20                                  |
| 17            | Mongolia           | 95% camel hair; 5% elastane         | 95.50                                  |
| 18            | Russia             | 70% wool (a picture of a camel on the label); 20% polypropylene; 10% elastane | 44.50                                 |
| 19            | Russia             | 15% camel hair; 55% wool; 24% acryl; 6% polyamide | 47.50                                 |
| 20            | Russia             | 60% camel hair; 40% polyamide       | 45.50                                  |
| 21            | Russia             | 50% wool; 50% acryl                 | 50.30                                  |
| 22            | Russia             | 50% wool; 50% acryl                 | 50.00                                  |
| 23            | Turkey             | 35% wool; 65% acryl                 | 35.50                                  |
| 24            | Germany            | 51% wool; 49% acryl                 | 52.30                                  |
| 25            | Italy              | 50% wool; 50% acryl                 | 21.30                                  |
Table 2. Results of determining mass fraction of special fibers in samples.

| Sample numbers | Producer (country) | Fiber structure, specified in products marking, % | Factual mass fraction of the most valuable fiber, % |
|----------------|--------------------|--------------------------------------------------|--------------------------------------------------|
| 7              | France             | 80 angora, 20 merino (sheep wool)                | 80 angora                                       |
| 8              | China              | 80 angora, 20 nylon                              | 51 angora                                       |
| 9              | Italy              | 70 angora, 10 merino (sheep wool), 20 polyamide   | 55 angora                                       |
| 10             | China              | 40 angora; 60 acryl                              | 2 angora                                        |
| 11             | China              | 35 angora, 40 merino (sheep wool), 15 nylon       | 30 angora                                       |
| 17             | Mongolia           | 95 camel fine hair, 5 elastane                   | 95.5 camel hair                                 |
| 18             | Russia             | 70 wool (a picture of a camel on the label); 20 polypropylene, 10 elastane | 0 camel hair                                   |
| 19             | Russia             | 15 camel hair, 55 wool; 24 acryl; 6 polyamide     | 0 camel hair                                   |
| 20             | Russia             | 60 camel hair, 40 polyamide                      | 5 camel hair                                    |

3.2. Using remote technologies for identification

Microscopy is the most widely used method in quantitative estimation of fiber content of products which consist of blends of sheep wool and hairs of rare animals.

When determining the belonging of fibers to certain species of animals one should rely on the peculiarities of epidermis, its relief, plastic distribution, thickness. Exploring the peculiarities of hair architecture of different species of animals continues, a range of studies is devoted to it [18, 19].

Identification of fibers requires special knowledge and experience because differences between certain fibers may not seem substantial at the first glance. Fibers of merino wool and cashmere are especially close by their morphological structure (figures 1, 2). The accuracy of results to a large extent depends on the experience and special knowledge of a research worker, as evidenced by Yue-qi Zhong's work [20].

Using a video eyepiece and specialized program software for microscopic investigation of samples allows dividing the process of expert estimation into stages which can be carried out at a distance from each other (figure 3).

The operator in point 1 prepares the samples which have been received for studying, undertakes a series of microscopic explorations preserving the captured images.

The operator makes a series of microscopic shots of viewing fields using the methods described in point 2.2. Microscopic shots of the viewing fields are being taken in the sequence depicted in figure 4 avoiding overlapping of the viewing fields. The image series with accompanying documents are forwarded to an expert in point 2 through communication channels.

The expert in point 2 accepts the information, carries out identification and calculates mass fraction of fibers using the obtained images, then he sends his conclusion to point 1.
In our opinion, the described order of carrying out expert investigations can be required for the work of a network of expert laboratories, geographically dispersed. Custom laboratories of forensic services serve as an example: they perform a range of various expert tasks every day. Applying remote technologies will allow to rationally using working capacities of expert laboratories, distributing tasks between them on an even basis. Besides, it will help to use special knowledge of experts to the fuller extent and contribute to close cooperation of independent laboratories. Also, identification with the
use of remote technologies will allow reducing the time for executing an expert evaluation thanks to excluding the time for transportation of samples.

4. Conclusions
The results of identification of textile goods containing valuable animal hair presented in this work give evidence of falsification of these goods on the Russian market. At the moment, microscopy remains a standard method of quantitative analysis of fiber composition of animal hair blends, though studies for improving and automating this labor consuming type of expert evaluation are being widely undertaken. The accuracy of results to a large extent depends on the experience of a research worker as there is a variety of difficulties during identification of these objects. The suggested order of applying remote technologies will allow executing expert evaluation of fiber composition even in the absence of an expert who has special knowledge and experience in this narrow field in a certain laboratory. It is quite sufficient that there is a specialist who knows the general methodology of microscopic examination of objects and of recording the results.

The described method can be actual for the work of a network of expert laboratories, geographically dispersed; it will allow to involve experts more rationally and to reduce the time for executing an expert evaluation.

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