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Analysis and Identification of Fibre Constitution of Archaeological Textiles

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The textile excavations founded at the time of dig process are called archaeological textiles. Due to injurious conditions when they are buried under the ground the polymeric structure of fibres and former colours are damaged, but the structure of fabric mostly remains. The modern technology of Fourier Transform Infrared Spectroscopy (FTIR) allows textile fibre constitution and sometimes the former colours identification. The comparison of various wool fibres in FTIR spectra showed the possibility of distinguishing some animal breed wool fibres and even fibres colours (the difference in natural white and black wool fibre's spectra was obvious). Investigations of archaeological textile of 13 – 14 century, which with the naked eye looked brown-black colour, showed that one of the textile was woven from white colour of the sheep wool fibre. The investigations of archaeological cellulose fibre textiles showed a lot of discrepancies. In spite of the fact that it is very difficult to identify the raw material with 100 % probability, but preliminary consideration is possible.
Keywords: archaeological textiles, spectroscopy, wool, cellulose fibres.

INTRODUCTION

A definition of archaeological textiles means excavations founded in cemeteries or other places at the time of dig process. Due to injurious conditions when they are buried under the ground the polymeric structure of the fibres and former colours become damaged, but the structure of the fabric mostly remains [1].

Unfortunately, archaeologists do not have special knowledge in textile. Therefore it is very important to create method for further analysis of archaeological textiles which can be easy to use. The preliminary investigations show that very important data for textile workers sometimes are forgotten by archaeologists and conversely. Only the complete information about excavations allows exhaustive analysis and an assumption how that textile was manufactured [2 – 6]. E.g. the analysis of archaeological textiles in given region can show the spread of horizontal weaving loom in different European countries. That also can be confirmed by some faults in the weave of the fabric.

The investigation of archaeological textiles can give information about technology spread and information interchange between nations and regions in the Middle Ages Europe. It is very important especially for countries which have not the own writing traditions for a long time.

The first objective of archaeological textile reconstruction is identification of fibre constitution. The modern technology (Fourier Transform Infrared Spectroscopy (FTIR)) allows to determine a fibre constitution of textiles and sometimes even the former red or blue colours (chemical analysis) [2, 7 – 10].

The goal of this work is to identify fibre constitution and former colour of archaeological textiles with Fourier Transform Infrared Spectroscopy (FTIR). The comparison of FTIR spectra of the different materials, which can be taken from different regions, different plants or animal breeds and which can differ in colour (natural black and white wool) and spectra of archaeological textiles were carried out.

MATERIALS AND METHODS

In the present research cellulose fibres (Lithuanian flax, hemp and nettle) and protein fibres were analysed. Important property which we would like to accent is that only pure fibre constitution were taken. It was done to avoid the chemical contaminants or other possible mechanical damage what could be done during the fibre preparation.

The detailed research on different breeds of animals (white sheep, black sheep, Cameroon sheep, white goat, black goat, camel, llama) wool and hair were done. The specimens have been taken straight from the Kaunas zoo. It enabled to compare not only Lithuanian region prevalent wool, but a foreign origin wool as well. The comparison in spectra of the different wool colours (natural black and white) was analysed additionally.

A sample of archaeological cellulose textile was taken from Žviliai cemetery (Šilale distr., Lithuania (Lithuanian national museum)) and a sample of archaeological protein textile was taken from Kriveikiškiai cemetery (Širvintos distr., Lithuania (Kernavė archaeological and historical museum)), both samples date back to 13 – 14 century.

The materials were analysed using computerised system of Fourier Transform Infrared Spectroscopy (FTIR-8400S) in the Restoration Centre of Lithuanian National Museum. A bulk analysis data were collected and converted from an interference pattern to a spectrum. The absorption of various infrared light wavelengths by the material was measured. The intensity of the infrared beam was measured before and after it interacted with the

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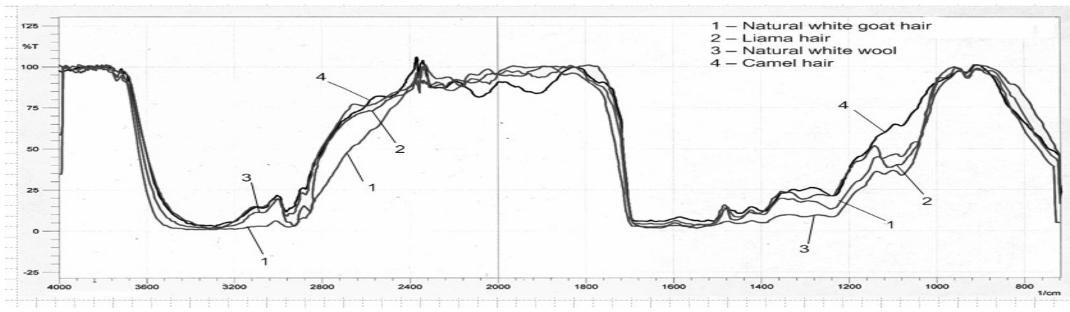

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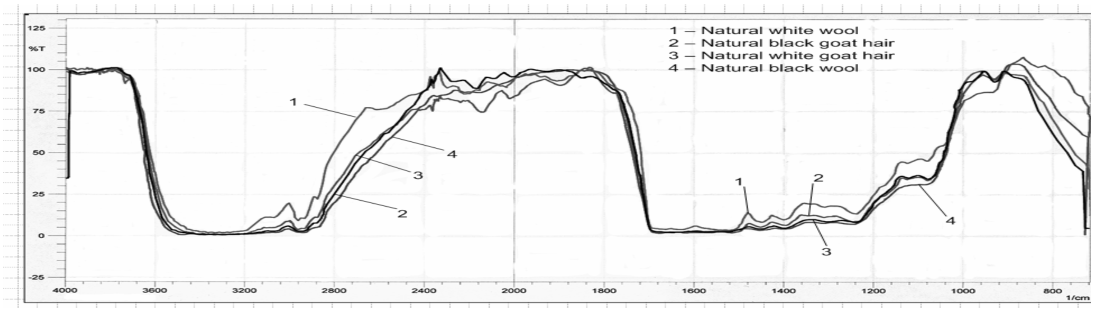

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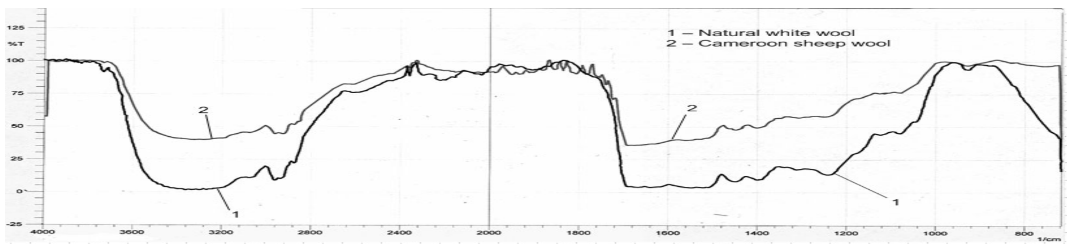

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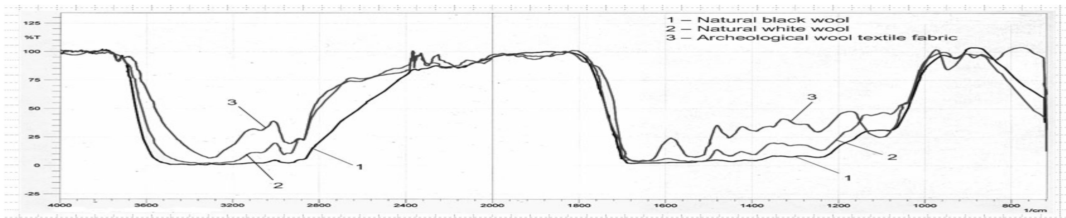

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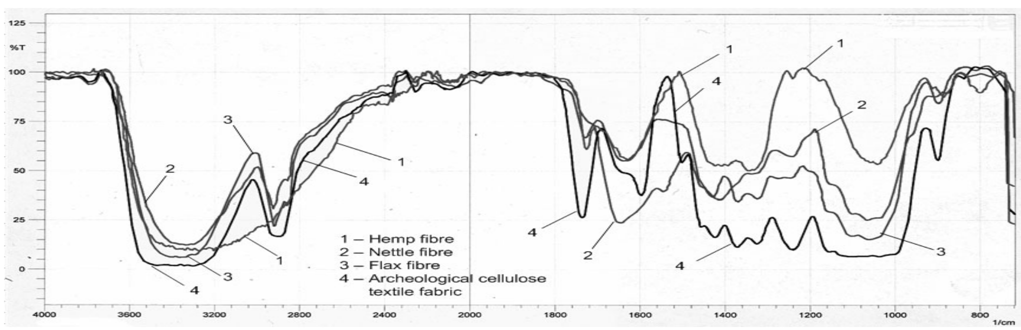

e

Fig. 1. Comparison of various fibres and archaeological textiles spectra (Notation of axes: axis of abscissas – transmittance (*T*) in percent, axis of ordinates – wave number in 1/cm)

sample, as a function of the light frequency which is expressed in reciprocal wave length, termed wave numbers (cm^{-1}). FTIR enabled us to measure weak signals with the high precision.

FTIR is very useful tool for identifying organic or inorganic materials. The chemicals from spills, paints, polymers, coatings, drug, and contaminants can be analysed. The known organic compounds were examined as well as unknown ones which later were identified by comparison to a library of known materials [11].

The experiment was performed with a Diamond Anvil Pressure Cell (DAC) sampling technique. A thin metal gasket containing a 250 µm diameter hole for encapsulating a sample was squeezed between the two anvils and analysed in the cell via standard infrared transmission. The accessory required a beam condenser which concentrates the infrared beam to a suitable size for the anvil windows.

RESULTS AND DISCUSSIONS

The comparison of spectra (representative diagrams) of various wool and cellulose fibres is presented in Fig. 1. White wool, white goat hair, llama and camel hair spectra are plotted simultaneously (see Fig. 1, a). It allows to carry out very precision comparison in the spectra infrared light absorption intensity. The common property for all fibres, which are analysed in Fig. 1, a, is a bright fibre shade (white for sheep, goat, llama wool and hair and tawny for camel hair). White wool fibre spectrum is chosen as a reading level. As we can see, white wool and llama and camel hair spectra are very similar to each other. The exception is white goat hair spectrum, which has sharper inclination in the frequencies region from 2900 cm^{-1} to 2400 cm^{-1} and have no visible peak in frequencies about 3100 cm^{-1}. So, plotting and comparing few different fibres in one plot simultaneously, identification of the fibre's constitution can be done. In this case white goat hair can be distinguished.

In Fig. 1, b, white wool, black wool, white and black goat hairs spectra are plotted simultaneously. As we can see, white wool, white goat and black goat hairs spectra are very similar. Few differences in the spectra are obtained in the infrared light absorption level in the frequencies region from 2500 cm^{-1} to 1900 cm^{-1}. It is known, that this frequency region depends on the air composition in the laboratory and it's interaction with different fibres [12]. So, it can not be used for the fibre constitution identification and further investigation. The high interest, which we would like to accent, is obvious difference in white and naturally black wool spectra. The sharper inclination and deflection for black wool spectrum in the frequencies region from 2900 cm^{-1} to 2400 cm^{-1} is noticed. The black wool spectrum has no visible peak at 3100 cm^{-1} meanwhile in the case of white wool spectrum the peak in the similar frequency zone is obvious. As it was noticed before the difference in white goat hair, black goat hair and white wool is not very clearly detected. In this case the fibres can be distinguished by using microscope. Usually goat and sheep natural fibres differ and can be recognised from the magnified surface structure. Microscopically, goat fire displays a scale structure like that of wool, but the scales are spaced more widely apart.

The fibres of different animals are analysed in Fig. 1c. The spectra of white and Cameroon sheep wool are plotted simultaneously. As we can see, the spectra are very similar and differ only in the absorbed infrared light intensity but not in the shape. In the case of Cameroon sheep wool (in the frequencies region from 3500 cm^{-1} to 2850 cm^{-1} and from 1700 cm^{-1} to 1050 cm^{-1}) more than 50 % of infrared light is absorbed. Meanwhile in the case of white wool (in adequate frequencies region) only a bit more than 1 % of infrared light is absorbed. The shape of spectra is very close – peaks of both spectra are in the same frequency region. So, even wool from very different regions (North East European and African in our case) can be identified as wool by the spectrum shape, despite the difference in amount of the infrared light absorption.

As we can see in the archaeological textile view (see Fig. 2), due to injurious conditions when the fabric was buried under the ground the brown-black colour appear.

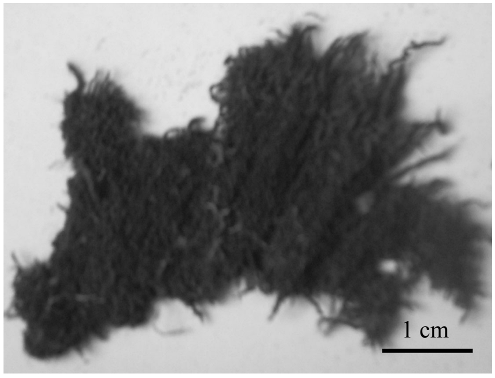

Fig. 2. View of wool-fibre archaeological woven fabric

The possibility to analyse the fibre origin as well as the former colour (white or naturally black wool) was checked with spectroscopy. In Fig. 1, d, the spectra of white wool, black wool and of archaeological textile fabric are plotted simultaneously. It is seen that archaeological textile spectrum looks are similar to the white wool spectrum. So, as a result of archaeological wool investigation the distinguishing of the former colour (white wool) can be implied, even if with the naked eye sample looks brown-black colour (see Fig. 2).

The analogous investigations were carried out with flax, hemp, nettle cellulose fibres and cellulose archaeological fabric (see Fig. 1, e). It is known that cellulose fibres are more vulnerable (when they are buried under ground) than protein fibres. So the analysis contains a lot of discrepancies as well. Flax, hemp and nettle fibre's spectra have a rise peak in the frequencies about 3000 cm^{-1} and a descent peak in the frequencies about 2900 cm^{-1}. In the case of archaeological textile in the frequencies region from 3200 cm^{-1} to 2600 cm^{-1} the spectrum gradually rises (no well-defined peaks are obtained).

Peak presence in archaeological textile spectrum in the frequencies region about 1700 cm^{-1}, 1650 cm^{-1} and 900 cm^{-1} show similarity to flax fibre, but in the frequencies regions 1700 cm^{-1}, and from 1300 cm^{-1} to 1000 cm^{-1} show similarity to nettle fibre as well. So, in spite of the fact that it is very difficult to identify the fibre constitution with 100 % reliability, the preliminary consideration is possible.

CONCLUSIONS

- The modern technology allowed to textile's raw material identification. The comparison of various wool and hair fibres of FTIR spectra showed the possibility of distinguishing some animal breed fibres and even fibres colours.
- The natural black wool spectrum can be distinguished from the white wool fibre's spectrum.
- White goat hair's and black goat hair's spectra do not differ and are similar to white wool spectrum.
- Wool even from the different regions can be identified as a wool fibre by the similar spectrum shape, despite the difference in amount of infrared light absorption.
- Former natural white colour of the wool can be implied in the archaeological textile sample.
- The archaeological cellulose fibre analysis has a lot of discrepancies. But in spite of the fact that it is very difficult to identify the raw material with 100 % probability, the preliminary consideration is possible.

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