FEATURES OF THE STRUCTURE OF WOOL FIBERS AND SOME PROBLEMS IN DYING OF WOOL FIBERS OF LOCAL ORIGIN

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Abstract. *The article shows the complex specific histological structure and chemical composition of wool fibers. The concentration, temperature and time conditions for the preparatory and dyeing processes of wool fibers of local origin, which were not previously used in textiles due to their coarseness and dark tones of various colors, have been established. The possibility of using them in the textile industry in the form of bleached and dyed fibers in various required colors has been proven.The cold method of dyeing local coarse wool has also been investigated. For the cold method of dyeing wool, only a solution of the diazo component was used, as the azo component, the amino acid residues of the wool fiber protein macromolecule react.*

Keywords: *structure, destruction, extraction, hydrophilic layer, wool fiber, enzyme, structure.*

Introduction

At present, the necessary legal framework and a favorable environment for the development of the textile and sewing and knitwear industry have been formed in the Republic of Uzbekistan.This presents great opportunities for the development of all textiles in general, in particular for expanding the range of textile products from natural protein fibers of local origin [1]. In light industry, sheep, camel and goat wool are used as wool raw materials. For the textile industry, sheep's wool is of the greatest importance [2]. The texture of wool fiber has significant features in contrast to other natural and chemical fibers.Wool fiber is a horn formation of epidermal origin, consisting of keratin protein.

Literature review

Carneiro et al. (2010), Perkins WS. [27], PrzystaśW.[28], Razumeev K.E. [29], Rigby B.J.[30], Robinson T.[31], Sen S . [32], ValchevaE.[33], Li XF [34], Zollinger, H. Synthesis [35]designed and optimized an accurate and sensitive analytical method for monitoring the dyes C.I. Disperse Blue 373 (DB373), C.I. Disperse Orange 37 (DO37) and C.I. Disperse Violet 93 (DV93) in environmental samples. This investigation showed that DB373, DO37 and DV93 were present in both untreated river water and drinking water, indicating that the effluent treatment (pre-chlorination, flocculation, coagulation and flotation) generally used by drinking water treatment plants, was not entirely effective in removing these dyes. This study was confirmed by the mutagenic activity detected in these wastewaters.

According to Barani, Montazer (2008), normally four different methods can be used for the preparation of liposomes:

Dry lipid film;
Emulsions;
Micelle-forming detergents;
Alcohol injection technology [34].

Liposomes have two distinct roles: they can provide an excellent model for biological membranes, and they are being developed as controlled delivery systems for hydrophilic and lipophilic agents [8,22]. They are promising

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candidates for adjuvant and carrier systems for drug delivery, are well-documented, and can be used for the same purpose in textile materials [8].

Analysis and results

Wool fibers have a heterogeneous histological structure. The fiber of fine wool consists of two layers - the outer scaly, or cuticle, and the inner cortical layer - the cortex. A coarser fiber also contains a core layer [3, 4–8]. The structure of the wool fiber is shown in (Fig. 1).

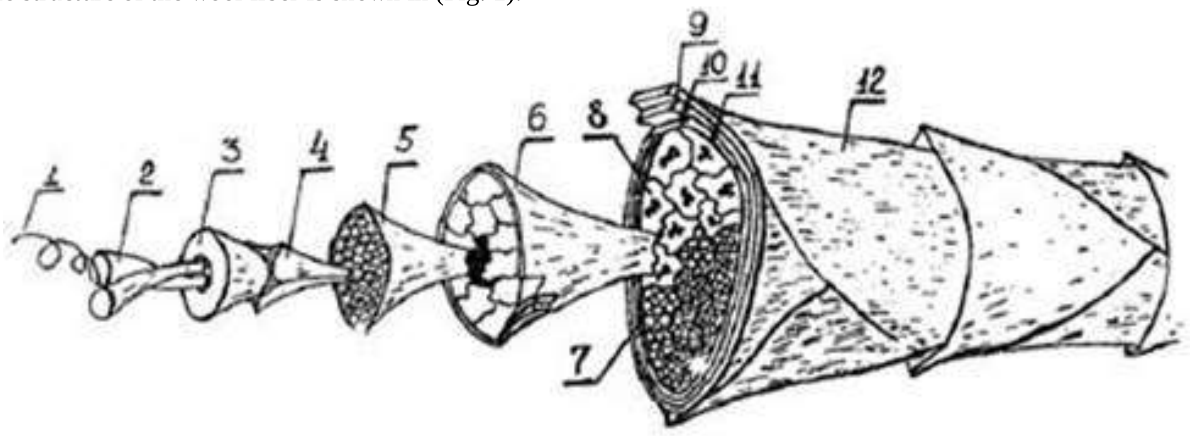

Figure 1. The structure of the wool fiber[9]:
1 –Right-handed α-helix; 2 –Left-handed coiled-coil rope; 3 –Microfibril (intermediate filament); 4 –Matrix; 5 -Macrofibril; 6 –Cell membrane complex;
7 – Ortho-cortical cell; 8 - Para-cortical cell; 9 - Epicuticle; 10 - Exocuticle;
11 - Endocuticle; 12 –Cuticle

The cuticle is the outer surface of the fiber, which protects it from mechanical, chemical and biological factors that affect the wettability of the wool and its felting[10,11]. In fine wool, the thickness of the scaly layer is the thickness of one cuticle cell, except when two scales overlap. The thickness of the cuticle of coarse fibers can reach 15 layers of scales [12]. The ability of the fiber to felting depends on the state of the cuticle scales, their integrity and density of adhesion to each other [3, 13, 14, 15].

Cuticle cells consist of two main layers: exocuticle and endocuticle, which differ in the content of cystine, and are surrounded by a thin protective membrane - the epicuticle [3,4,7,14]. The epicuticle, being highly resistant to acids, oxidizing agents, reducing agents, enzymes and, to a certain extent, alkalis, forms a diffusion barrier for the penetration of chemicals into the fiber.

A thicker layer adjoins the inner side of the epicuticle - the exocuticle, which is a protein with high hydrophobicity, high sulfur content and a high degree of cross-linking of polypeptide bonds, which makes it extremely resistant to the action of enzymes and chemical reagents.

The deepest layer adjacent to the cortex is the endocuticle, a hydrophilic layer with a low sulfur content, which consists of non-keratin remnants of the cytoplasm and pre-existing follicles, is soluble in acid and is not resistant to enzymes [10, 11, 16].

The cortical layer (cortex) is located under the cuticle, makes up the bulk of the fiber and determines the main physical, mechanical and, in many respects, chemical properties of wool.

It consists of spindle-shaped cells located in the direction of the length of the fiber, rather tightly pressed against each other. Fusiform cells of the cortical layer consist of macrofibrils, which in turn consist of microfibrils with a diameter of about 0.05–0.2 μm and of various lengths, arranged in bundles and having an ordered crystalline structure in places, but mainly characterized by a disordered amorphous structure [4].

The voids separating the macrofibrils are filled with intermacrofibrillary substance rich in cystine. Macrofibrils consist of microfibrils, which, in turn, are divided into protofibrils - helical interweaving of two or three a-helical chains (amino acids). The fibrillar supramolecular structure of keratin is characterized by a high degree of orientation and crystallinity and is immersed in an interfibrillar substance - a matrix similar in structure to keratin, but having an amorphous structure [13].

All cells of the cortex into a single system connects the cell-membrane complex that occurs at the final stage of the formation of wool keratin between the membranes of the cells of the cortex and cuticle. This layer differs from the membranes of living cells by a low content of phospholipids and consists mainly of proteins, free fatty acids and waxes (cholesterol and desmosterol) [17].

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The core layer is present in coarse wool fibers, in which the content of core cells reaches 15% [3]. The scaffold of the cells of the core layer consists of a protein similar to the cortical microfibril protein, but in the core layer the microfibrils are oriented along the transverse walls, and not along the fiber, as in the cortical layer. The proteins of the core layer are distinguished by a very low content of cystine and are relatively resistant to the action of various chemical reagents, including caustic alkalis. The high chemical resistance and insolubility of core cell proteins is explained by the presence of amide cross-links formed by lysine amino groups and carboxyl groups of glutamine or aspartic residues of nearby peptide chains [12].
It is established that the chemical structure of the fiber consists of proteins. The structure of proteins contains - 50.3 - 52.5% carbon, 6.4 - 7.3% hydrogen, 16.2 - 17.7% nitrogen and 20.7 - 25% oxygen [18]. In addition, the amino acid composition of wool fibers is well studied, however, it is noted that for the whole wool fiber and its histological elements it differs significantly [19].

By structure, keratin is a complex complex containing bundles of high-molecular chains interacting both in the longitudinal and transverse directions
The main polypeptide chains of keratin are oriented along the fiber and are connected by a large number of transverse side bonds due to salt, covalent and hydrogen bonds, as well as Van der Vaalsforces [16,17, 20].

The formation of salt bonds between polypeptide chains in the macromolecule of keratins is due to the significant content of basic (arginine, histidine, lysine) and dicarboxylic amino acids (aspartic and glutamine).
The main covalent bond between polypeptide chains is a disulfide (cystine) bond that firmly connects the polypeptide chains of keratin.

The disulfide bond causes a number of specific chemical and physico-mechanical properties of wool, for example, complete insolubility in water and organic solvents, special strength and high elasticity of the fibers [16]. Disulfide bonds can be modified, destroyed or strengthened and cause significant changes in the chemical and physical-mechanical properties of the fiber [7, 12].

Hydrogen bonds are formed between groups of peptide bonds (-CO-NH-) of neighboring polypeptide chains, and also due to a significant amount of hydroxyl-containing amino acids (serine and threonine).

The structure of the side chains largely determines the physicochemical properties of proteins: the position of the isoelectric zone, the ability to solvate and hydrate. Active functional groups in the side chains mainly determine the chemical reactions inherent in protein substances [17, 20,16, 13].

For the textile industry, sheep wool is of the greatest importance, which is divided into types depending on the fineness: fine, semi-fine, semi-coarse and coarse [2,3].

Fine wool mainly consists of fine, finely crimped down fibers, has a staple structure and is highly uniform in fineness and length. The average fineness of fine wool varies within 14.5-25 microns, the average length is 40-70 mm. Fine wool with an average length of more than 55 mm goes to combed spinning, and less than 55 mm to machine spinning [17].

Semi-fine wool consists of fibers of down or a thin transitional hair. It is distinguished by uniformity in fineness and length, has a staple structure and a larger crimp of the fibers than that of fine wool.

The average fineness of semi-fine wool is 27 microns. According to its technical properties, semi-fine wool approaches fine wool and is intended mainly for the production of combed yarn [2,20]. Semi-coarse wool is heterogeneous, it consists of fluff and transitional hair with a small admixture of fine awns and has a braided structure. To semi-coarse wool can also be attributed to a homogeneous coat, consisting of a thin awn and transitional hair.

Coarse wool has a braided structure and is a heterogeneous mixed wool, as it is characterized by the presence of all types of wool fibers: fine fluff, transitional hair, dry and dead hair. The ratio of different types of fibers in wool can be 16 different depending on the breed and intrabreed characteristics of sheep, what determines the value of coarse wool.

The natural color of wool fibers is given by pigments located in the cortex of the fiber in the form of ellipsoidal granules. Microscopic studies show that the pigment is mainly located in the interfibrillar substance, and the number of colored granules increases from the center to the surface of the fiber [17]. Part of the pigment is located diffusely in the fiber. In the paracortex, its content is greater than in the orthocortex. A certain proportion of the pigment was found in the scaly layer.

Pigment formation occurs during hair growth and is associated with partial hydrolysis of the formed proteins to tyrosine, the oxidation of which in the presence of the tyrosinase enzyme and subsequent polycondensation lead to the formation of colored products – melanins[20, 21]. Depending on the sources of formation, melanins are divided into eumelanins and pheomelanins. The source of the formation of eumelanins is tyrosine, from which pigments containing C, H, N and O are formed. The sources of pheomelanins are tyrosine and cysteine, which are converted into sulfur-containing pigments [22, 23].

The pigment pheomelanin gives the fiber a pink-red hue depending on the concentration. In sheep's wool, pheomelanin is found in small amounts, unlike eumelanin.

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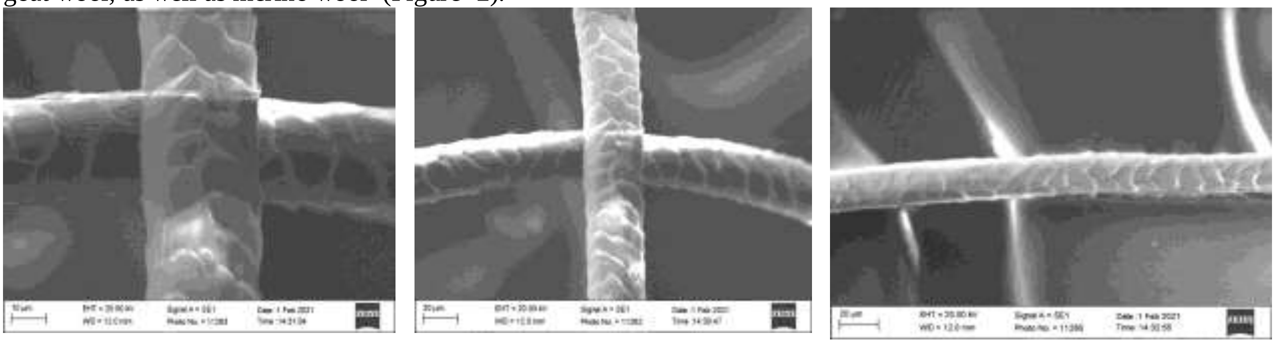
Eumelanin is of two types: brown and black and differ from each other in the structure of the polymer. A small amount of black eumelanin in the fiber, in the absence of other pigments, gives the coat a gray color, and a small amount of brown eumelanin gives a yellow color. The diversity of initial monomers and the high activity of intermediate products make the chemical composition of melanins diverse and the polymer structure irregular. The greater chemical stability of naturally dyed fibers compared to white ones that do not contain pigment is explained by the formation of mesh structures due to the interaction of melanins with sulfhydryl and amino groups of keratin.

Fine wool fiber is usually colorless and can be made into an assortment of fabrics in a variety of colours. Coarse wool fibers of local origin are yellowish brown to dark brown, gray or black, and this creates a problem for dyeing wool into various desired colors. At the same time, the pigment substances that give the fibers color are chemically bound by the keratin of the wool. In the preparatory processes of wool, especially when bleaching and bleaching, it is necessary to take into account the preservation of keratin, without damaging it [24].

Researcher Z. Islamova conducted a comparative study of the structure of wool fibers of local sheep and goat wool, as well as merino wool (Figure -2).



A B C

Figure 2.X-ray diffraction pictures:
A-fibers of local coarse wool, , B- local goat wool fibers,
C-merino wool fibers

As shown in the figure, the fibers of sheep and goat wool do not differ in the nature of the morphological structure. But they differ in fiber diameter; local rough sheep wool has fibers in size - 55.35 µ, goat wool - 34.0 µ, merino wool - 22.5 µ. The fibers have a shape close to cylindrical. The size, shape and nature of the relative position of the scales depend on the type of wool (fine or coarse) and affect many of the technological and operational properties of the fiber.

We have carried out the processes of washing, bleaching, bleaching sheep wool fiber of local origin with the help of various reagents. The composition of the bleaching solution included: hydrogen peroxide - as a bleach, sodium silicate as a stabilizer, various surfactants. Studied the effect of temperature and duration of processes on the quality of wool [25].

The influence of various organic solvents (perchlorethylene, heptane with acetone, tetrachlorethylene) on the efficiency of fat removal was also investigated. It has been established that perchlorethylene is the most effective solvent for wool fat, because in the wool fiber samples in this case, 1.8% residual fat was found without a decrease in the length of the fibers, which corresponds to the norms of coarse wool [26].

Due to the very high sensitivity of the wool fiber to high temperatures and to concentrated solutions of chemical reagents, dyeing methods that provide minimal damage to the fibers at low temperatures are of the greatest practical interest. The maximum preservation of the strength properties of wool fiber during dyeing is one of the factors for improving further mechanical processing processes in the spinning industry. Lowering the temperature of wool dyeing by 15-200C helps to reduce the consumption of energy, water and steam [27], which is one of the ways to achieve resource saving in the dyeing and finishing production of textile enterprises. Preservation of all quality indicators inherent in wool fibers in the processes of chemical and mechanical finishing is very important. In this aspect, the method of cold dyeing of fibrous materials with insoluble azo dyes is more resource-saving [28].

We have studied the cold method of dyeing local coarse wool. For the cold method of dyeing wool, only a solution of the diazo component was used, as the azo component, the amino acid residues of the wool fiber protein macromolecule react.

Dyeing of wool after preparatory processes for dyeing was carried out by treatment with a diazonium salt solution containing a surfactant. As a diazonium salt, a solution of diazole orange O was used. In this case, the color of the coat turns out to be from light orange to dark orange [27].

Conclusions

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Thus, it can be concluded that wool fiber is a natural composite material. Unlike plant fibers, wool has a very complex histological structure and chemical composition.

The specific mechanical properties of wool essentially depend on all levels of its structural organization, as well as on the morphology of the fiber. The presence of a scaly layer and its condition determines such technological properties of wool as strength, felting, wettability, which affect the quality of finished products [29]. Based on the results of the research, the concentration, temperature and time conditions for the preparatory and dyeing processes of wool fibers of local origin, which were previously considered non-discoloring fibers due to their coarseness and dark tones of various colors, were established. The possibility of using them in the textile industry with dyeing bleached fibers in various required colors has been proven.

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