Theoretical And Methodological Analysis Of The Strength, Moisture Content And Chemical Properties Of Local Coarse Wool Fiber

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Abstract

This article analyzes the physical, mechanical and chemical properties of local coarse wool fiber from a theoretical and methodological perspective. The structure of wool fibers, namely the sheath, core and core layers, their influence on strength and elasticity are scientifically explained. In addition to the thickness, length, twist and strength of wool, its hygroscopicity, thermal conductivity and electrical properties were studied in the study. The technological properties of wool fibers - spinnability, wettability and dyeability - were also extensively analyzed. The fact that wool is grown in different regions, animal breeds, age and climatic conditions directly affect its quality and durability is substantiated with scientific examples. The author shows the moisture properties of wool, its hygroscopicity and comparisons with other textile fibers using clear tables and data. At the same time, modern methods of measuring the strength and tensile strength of wool are also discussed. The results of the research are of practical importance in the processing, cleaning of wool fibers and improving the quality of products made from them. This article serves as a scientific and theoretical basis for the efficient processing of coarse wool resources and the textile industry.

Keywords: Sheep wool, scaly layer, core layer, medullary layer, elasticity, coarseness, hygroscopicity.

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1. Introduction

Sheep wool is the fiber obtained from local breeds of sheep. Currently, sheep wool accounts for more than 80% of the total balance of all types of wool raw materials. In terms of quality, sheep wool represents the broadest range of wool fibers, from which the finest wool fabrics and other woolen products are made. The development of the wool processing industry and the creation of technological processes are entirely based on the resources of sheep wool.

2. Methods

Structurally, wool fiber is divided into three layers:

1. **Cuticle layer (scaly layer)** — consists of horn-like scaly cells that cover the fiber body externally, protecting it from decay, strengthening the fiber, and improving its compressibility.
2. **Cortical layer (core layer)** — composed of microscopic cells that form the wool fiber and serve as the main layer determining its strength, elasticity, and other properties.
3. **Medullary layer (inner or central layer)** — a layer filled with fibrous material located between the wool fibers.

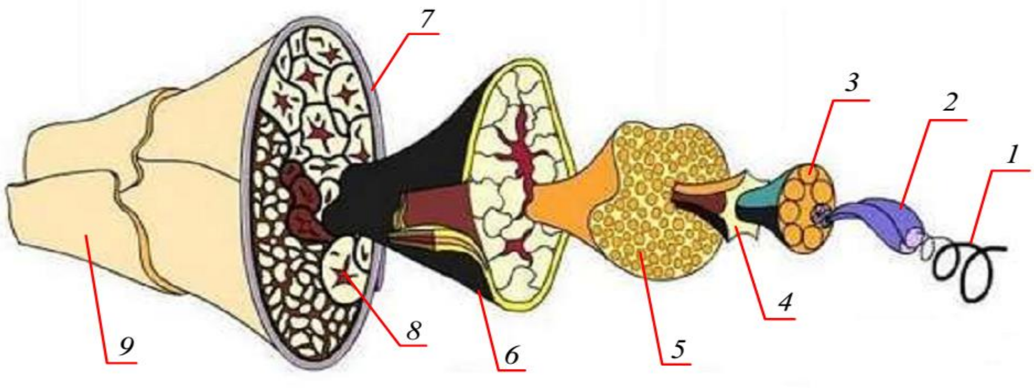

Figure 1.2. Structure of Wool Fiber

1 – alpha-helix; 2 – protofibrils; 3 – microfibrils; 4 – matrix; 5 – macrofibrils;

6 – cortical cell; 7 – orthocortex; 8 – paracortex; 9 – cuticle (epicuticle, exocuticle, endocuticle).

Physical and Mechanical Properties of Wool Fiber

The physical and mechanical properties of wool fiber include: thickness, length, crimp, strength, color, elongation at break, hygroscopicity, luster, thermal conductivity, and electrical conductivity.

Wool fibers are classified by thickness and structure into the following types: downy, intermediate, coarse, and medullated fibers.

The properties of wool fibers can be divided into two major groups:

a) Technological properties of the fiber include spinnability, wettability, and dyeability.

b) Physico-chemical properties refer to the fiber's interaction with various substances (water, hot air, acids, alkalis, etc.).

The specific density of wool fiber ranges from 1.28 to 1.33 g/cm³, and in humid air, it can absorb up to 40% water. Normal air humidity is 15–17%. The appearance of a single wool fiber in a free state is curly.

Fibers measuring 1 cm in length show 7–12 twists in merino wool, 5 twists in semi-coarse wool, and 0.2–0.5 twists in coarse (staple) fibers. Sheep wool can vary in thickness from 5 to 160 µm and in length from 25 to 350 mm or more.

These properties of wool fiber depend on its formation in the animal's skin, nutrition, natural-climatic conditions of the region, age, and, most importantly, the sheep breed. On average, sheep wool grows at a rate of 0.6–0.8 mm per day. On average, one sheep yields about 6 kg of wool; this value also depends on fiber diameter, age, and sex of the sheep. Among coarse-wool breeds, productivity can reach 75–80% or more.

In semi-coarse and coarse wool, the main types of crimps are observed (see Figure 1.2).

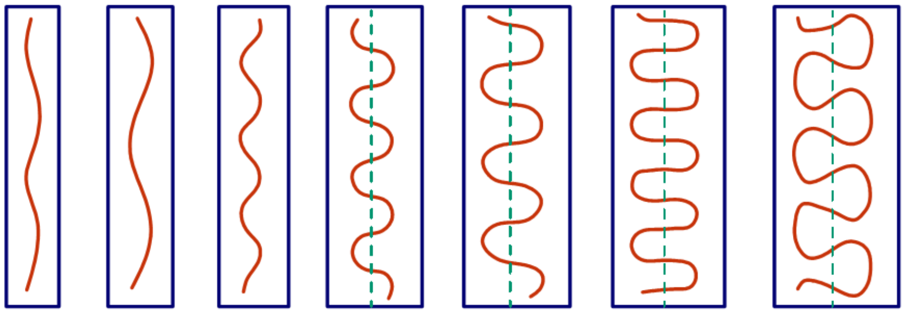

Figure 1.2. Wool Crimp Shapes

1 – smooth; 2 – elongated; 3 – flat; 4 – simple; 5 – high; 6 – compressed;

7 – looped.

The wool crimp types listed above can be divided into three groups: normal, weak (smooth, elongated, and flat), and strong (high and looped).

The uniformity of wool and its individual sections in terms of density is primarily determined by the breed and individual characteristics of the sheep. At the same time, wool unevenness is caused not only by its density but also by differences in length, thickness, coarseness, and other properties in different areas of the fleece, which in turn are determined by variations in the condition of the skin across different parts of the body surface (see Table 1.1).

(Table 1.1).

Distribution and Thickness of Wool on the Sheep's Body

Wool Name by Body Part	Thickness and Micron Index											
	12	14,4	16,8	19,2	21,6	24,0	26,4	28,8	31,2	33,6	36,0	Overall
	number of fibers, percentage											
Shovel / Blade..	3	28	40	22	5	1	-	1	-	-	-	100
Side......	-	3	14	16	30	16	8	2	1	-	-	100
Fragment / Chip............	-	1	9	18	22	18	14	7	3	3	1	100

In connection with the above, it can be seen from the table that the alternation of thicker and thinner sections along the wool length can vary greatly depending on the conditions under which the wool grows.

Wool strength is the resistance of wool fibers to tensile forces. These forces are usually expressed in grams of load applied to break the fiber. The load that causes the wool fiber to break is called the breaking load and represents the fiber's absolute strength.

In modern practice, wool strength is not measured along the entire fiber length but on individual sections of the fiber at intervals of 10 mm.

Wool elongation refers to the increase in the length of wool fibers. This does not involve lengthening the fiber by straightening its crimps, but rather the actual elongation of a pre-straightened fiber.

By observing the elongation of wool fibers using appropriate instruments called dynamometers, slow elongation relative to the original fiber is determined, and the elastic elongation of the fiber is calculated.

Elasticity is the ability of wool to restore its original size and shape after the cessation of certain mechanical effects.

The greatest influence on the strength and elongation of wool fibers under atmospheric conditions is exerted by air humidity. The relationship between the strength and elongation of wool of different thicknesses is presented in Table 1.2.

(Table 1.2).

Strength and elongation of wool of various thicknesses

Thickness and micron index, mkm	Tensile strength, % …from-…to	Strength, sN/tex…to…
18 and thinner	20,0-48,5	3,98-5,74
18-20	28,0-50,0	5,70-6,98
20-22	29,0-56,5	7,19-8,55
22-24	32,0-50,5	7,70-9,54
24-26	35,0-57,5	9,36-11,76
26-30	30,0-65,5	13,26-16,86
30-37	37,5-62,0	16,47-22,79
37-45	40,0-67,5	29,30-38,66
45-60	32,5-65,0	39,20-48,40
60 and above	40,0-63,5	51,25-63,25

The moisture content of wool is the amount of water it contains. It refers to the water remaining in the wool, which is not sufficiently dried from the air, after the washing process or after soaking. The moisture content of wool refers to the water that is mechanically retained in it and is not part of the chemical composition of the wool fiber. The moisture content of wool largely depends on its hygroscopic properties. The hygroscopicity of wool is its ability to absorb water from the air, and this property is highly developed.

The moisture content of wool fibers absorbed from the air is measured under normal conditions at 15 to 18%, i.e., at normal humidity, there are 15 to 18 kg of water for every 100 kg of absolutely dry wool. As the humidity in the atmosphere increases, the moisture content of the wool also increases, sometimes reaching 30-40% or more in an atmosphere saturated with water vapor. Wool strongly retains absorbed moisture, and its complete removal is achieved only by drying the wool at high temperatures (105-110 ° C).

Compared to other textile fibers, wool is characterized by its highest hygroscopic ability, as shown in Table 1.3 below.

(Table 1.3).

Moisture content of various types of textile fibers under average atmospheric conditions

Types of textile fibers	Humidity, %
Wool ……………………………………	16,0
Rayon (viscose) ………………………..	16,0
Linen……………………………………	12,0
Silk……………………………….........	11,0
Cotton…………………………………	8,8

The hygroscopicity of wool is a variable value, depending on various factors. Its change depends on various internal and external factors, mainly on the humidity of the surrounding air. It also varies depending on the time of year and the geographical location of the area. Humidity standards are expressed as a percentage of the absolutely dry weight of the wool after drying, and not on the initial weight of the wool before drying.

(Table 1.6).
The moisture content of washed and dirty wool is given at different relative humidity.

The name of wool	Relative air humidity, %						
	43,3	55,4	62,3	74,6	81,5	86,2	90,0
	Wool moisture, %						
Pure wool	12,24	14,37	15,62	16,5	17,8	19,2	20,8
Dirty wool	7,6	9,25	10,87	13,0	15,1	17,3	19,45

100 kg of washed wool with normal wool moisture content contains only 85.5 kg of absolutely dry wool. This can be seen from the following calculation: the moisture content of wool is 17%, so every 100 kg of absolutely dry wool gives 117 kg of normally wet wool (100 kg of absolutely dry plus 17% water). Here dry wool is 100 kg, wool with normal moisture content is 117 kg, absolutely dry wool is x, and normally wet wool is 100 kg.

$$x = \frac{100 \cdot 100}{117}, yoki\ 85{,}5\ kg.$$

If 85.5 kg of completely dry washed wool, due to appropriate moistening, reaches a weight of 100 kg, this corresponds to a water content of 17% in the wool, i.e., the moisture content.

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