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"ITALIAN HIKOL RABBIT (ORYCTOLAGUS CUNICULUS) WOOL: COMPOSITION, PROPERTIES AND ITS POTENTIAL AS A RENEWABLE SOURCE FOR THERMAL INSULATION MATERIALS"

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Abstract: This scientific article analyzes in detail the chemical composition, physical properties and structure of wool of the Italian breed of Hikol rabbit (Oryctolagus cuniculus). The importance of wool as a renewable and sustainable resource, as well as its potential in the field of production of thermal insulation materials, is studied. The results of the study showed that Hikol rabbit wool has excellent thermal insulation properties and substantiated the possibilities of using it as an environmentally friendly and effective source of replacement for traditional materials in the construction industry.
Keywords: Italian breed of Hikol rabbit, Oryctolagus cuniculus, wool, composition, properties, thermal insulation, renewable resource, sustainability, building materials, environmental friendliness.

Introduction. In the 21st century, the world community is setting itself such important tasks as energy efficiency, the development of environmentally friendly technologies and the rational use of natural resources. Today, many traditional materials (artificial fibers, fabrics obtained from petroleum products, etc.) that are widely used in the production of special clothing are made from non-renewable resources. Their production process has a negative impact on the environment and creates problems with waste disposal. Therefore, the issue of using environmentally friendly, renewable and sustainable raw materials in the design of special clothing is gaining urgent importance. In recent years, there has been increasing interest in recycling agricultural waste and obtaining new, useful products from them. In particular, the use of wool produced in the rabbit industry as a thermal insulation material is a promising direction. Rabbit wool is a natural, renewable and environmentally friendly material with excellent thermal insulation properties. Due to the large number of air-retaining voids in its structure, its thermal conductivity is low.

Italian breed Hikol rabbits are distinguished by the high quality of their wool. The wool of this breed of rabbits has a thinner and denser structure than that of traditional breeds, which increases the effectiveness of thermal insulation materials made from it. Also, the process of raising Hikol rabbits and collecting wool is relatively inexpensive and environmentally friendly.

The purpose of this scientific article is to analyze the composition, properties and potential of the wool of the Italian breed of Hikol rabbit as a renewable resource for thermal insulation materials. During the study, the chemical composition, physical properties (thermal conductivity, density, moisture absorption), structure and microstructure of the wool are studied. Also, the environmental and economic advantages of thermal insulation materials obtained from Hikol rabbit wool are compared with traditional materials.

The results of this research can contribute to the expansion of the use of environmentally friendly and effective thermal insulation materials in the construction industry, the recycling of agricultural waste and the development of the rabbit industry. The information presented in the

article is expected to be useful for scientists, engineers, builders and agricultural specialists. Also, based on the results of this research, it will be possible to create new types of thermal insulation materials and improve their production technologies in the future.

Thermal insulation fabrics are widely used in various industries, including construction, automotive, clothing, and medicine. In the production of nonwoven fabrics, a wide variety of textile fabrics based on natural fibers [1] and synthetic fibers [2] are produced.

Globally, polyester fibers are mainly used as a thermal insulation layer in the production of warm clothing. The ability to form polyester fibers to any desired thickness allows you to obtain heat-retaining materials with a dense structure from them. In addition, due to the electrification of the fiber, the fibers move away from each other, and the resulting air layer also ensures the heat resistance of the product. However, the European Commission is implementing a number of projects to reduce the release of microplastics into wastewater and prevent microplastics from entering the human body [3]. In this regard, special attention is paid to replacing polyester fibers with biodegradable natural fibers [4].

Today, there are a total of 18,032 livestock farms in our republic, of which 254 are organized in the rabbit breeding sector. In order to fulfill the tasks of the Resolution of the Cabinet of Ministers “On measures to further improve scientific activities in the field of rabbit breeding in the republic” No. 647 dated August 2, 2019, it is necessary to raise at least 280 thousand female rabbits and about 40 thousand male rabbits of breeding breed in Uzbekistan per year. Due to the low negative impact of rabbits on the environment compared to other types of livestock farming, it is considered an environmentally friendly direction [5]. It is planned to further expand the network of processing organizations in the rabbit breeding sector in order to produce value-added products for the industry and reduce the volume of imports from the Republic [6]. In this regard, it is important to expand the areas of application of rabbit fluff and expand the range of products based on it. Currently, the most common breeds of rabbits in our country are the "Albus Giganteus", "Griseus Giganteus", "Albus mollis", "Hypplus", "Hikol", and "Angora" [7].

Economically, rabbit farming is a profitable industry due to the high demand for rabbit wool, as well as rabbit meat. The highest quality scarves and other textile products are made from rabbit wool. [8]. Rabbit wool is of great importance in the national economy. Wool fibers are combed from individual breeds (Angor, Kirov, and White rabbit breeds). From each rabbit, 150-170 g of wool can be obtained once combed, and 5-6 times during the year. Thus, on average, from each rabbit during the year, from 450 g to 1020 g of wool can be obtained [9]. Rabbit wool is not inferior to fine-fiber sheep wool (merino) in terms of fineness, durability, and heat transfer [10].

Rabbit wool is an important fiber in the textile industry as a fiber with a twisted structure, insulating properties, and biodegradable properties. The valuable properties of wool fiber are due to its morphological structure and chemical composition [11]. Rabbit wool is very soft, so the service life of products made from it is set at 3 years. However, due to the fact that the cut rabbit wool does not twist and sheds less, the products made from it last longer, and in addition, the lightness, softness, and thinness of rabbit wool are among its positive properties [12].

Rabbit wool is considered the most suitable fiber for thermal clothing, and more importantly for people suffering from arthritis and allergies. Clothing made from pure rabbit wool is distinguished from other wool products by its extreme warmth. Although rabbit wool has low strength due to its extreme thinness, it is one of its positive properties in obtaining dense structured yarns and fabrics. Typically, rabbit wool is mixed with about 20% of other animal fibers, such as sheep wool, to increase the strength, abrasion resistance, and elasticity of products made from rabbit wool [13].

Methodological part. Research object: In our research, the object was the white rabbit wool of the “Hikol” breed, created through Italian selection, bred by the agricultural enterprise “Rabbit breeding and breeding agro complex”. The Hikol breed is known as “Oryctolagus cuniculus hybridus Hikol”. The diameter of the rabbit wool fiber is 18.6 μm and the length is 18-22 mm.

Wool fiber washing method: The wool fiber washing process is carried out in the “Water bath shaker DL-2003” (Korea) equipment. The solution preparation process is carried out in the Laboratory Testing Machines “DLS-6000” device.
The wool fiber is washed in a solution containing 2 g/l sodium carbonate and 2 g/l soap. The process is carried out in a solution with a module of 1:50 at a temperature of 60 °C for 45 minutes. The pH of the washing solution is determined using the Wissenschaftlich-Technische Werkstatten (WTW) pH3210 SET2 device. Then the samples are washed first in cold water, then in water with a temperature of 40 °C for 10 minutes, then again in cold, warm water for 10 minutes and dried. Before checking the quality of the samples, they are stored in a standard environment in the TEMP.&HUMIDITY Chamber – DL-105SG for 24 hours until they reach a constant mass.
The color intensity of wool fibers (Korea) was determined on an “X-Rite Ci7800” spectrocolorimeter and calculated using the Gurevich–Kubelka–Munk function [14].
Discussion of the results of the experiment. The possibilities of using rabbit wool in the layer of clothing to provide heat-retaining properties were studied within the framework of this scientific work. The morphological structure of rabbit wool is very different from that of other animals. To date, a lot of information has been presented in the literature on rabbit wool, but due to the lack of complete information on its morphology, a large amount of wool has not found its place in industry [15].
Due to the low fat content of rabbit wool, it does not retain dust and does not cause allergies. Sheep wool contains a large amount of fat and various waste. Fatty substances are removed from the fiber during the washing process, and vegetable substances are removed from the fiber during the carding, spinning and carbonization processes [16].
The low content of dust and various mineral wastes ensures resource efficiency in the primary processing of rabbit wool. However, the low amount of cellulose-containing waste also complicates the fiber processing process. Therefore, the wool is cleaned of cellulose waste during the primary processing of the wool, and then during the carbonization process of the prepared nonwoven fabric with sulfuric acid [17, 18]. During the carbonization process, plant-based wastes are destroyed and leave the fiber composition.
The quality indicators of the thermal insulation material being prepared are significantly affected by the morphology of the fibers. In the studies, the morphology of the fibers was analyzed using electron microscopic observations. In the morphology of the wool, the surface properties of the fiber and the shell-like layer determine its physical and technological properties, such as elasticity [19], twisting [20],softness and heat resistance [21].
Rabbit wool is usually a long, hollow, twisted fiber with a smooth surface. The conical layer on the surface affects the hygienic and thermal insulation properties of the fiber [22]. The conical layer traps air, forming an air layer. Poor air permeability provides thermal insulation properties to products made from it.
In fact, wool used in the textile industry is considered to have the same properties regardless of its origin [23]. However, although the chemical composition of wool fibers obtained from different animals is the same, their physical structure differs from each other [24]. The physical structure and morphology of wool obtained from different animals certainly affect its consumer properties, and it is impossible to satisfy all the requirements for the corresponding product with a fiber belonging to one species [25]. Therefore, wool and its compositions with other fibers are organized according to the type of finished product to be produced and the relevant requirements placed on it [26].
From the data presented in the figure, it can be seen that karakul wool has the highest moisture retention capacity with 13.5%. This is explained by the presence of a large number of capillaries and micronochia on the surface in its morphological structure. This value in rabbit wool is 0.2% and 0.8% more moisture compared to the moisture content in camel and sheep wool, respectively. The fact that the moisture content of karakul wool is 3.5% higher than that of rabbit wool is due to the fiber size. Rabbit wool is very soft and has a high heat retention capacity and has the best

moisture-wicking properties among any natural fibers, that is, it wicks moisture away from itself. The moisture permeability of rabbit wool fibers under standard atmospheric conditions - at a temperature of 21^0C and a relative humidity of 65% - is 12.6-13.3%, sheep wool - 14.8-15.9%, camel wool - 12.3-13.8%, cotton fiber - 7-8.5% [27]. This value is equal to 0.4-0.8% for artificial fibers such as polyester, compared to natural fibers.

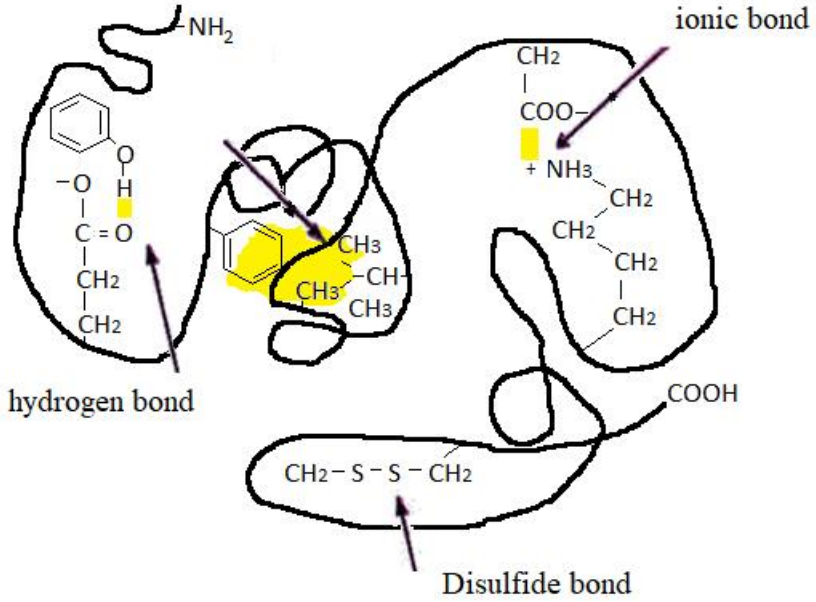

Figure 1. Hydrogen and disulfide bonds that form in a protein macromolecule.

Rabbit wool fibers are of three types: guiding fibers, core fibers, and downy fibers. The guiding fibers are 100 to 110 mm long, they guide the growth of other fibers and cover them. The core fibers are 80 mm long and have a rough surface. Due to the unevenness of the fiber surface, they are intertwined with each other, and these fibers cover the downy surface. Downy fibers are 60 mm long, have a very smooth surface and a small cone-shaped layer. The diameter of downy fibers is 14 μm, which makes them the thinnest animal fiber [28]. Due to the softness of all fibers in rabbit wool, i.e., the channel space, the weight is almost 0.8-13.5% less than that of all other animal wools (Table 1), in addition, this space also provides the thermal insulation properties of the fiber [29].

Table 1

Properties of wool fiber

№	Wool fiber / Material	Density (g/cm³)	Notes
1	Rabbit fur (Hikol)	0.95 - 1.15	Density can vary depending on the breed of rabbit, type of wool, and processing process.
2	Sheep wool	1.25 - 1.35	The density of sheep's wool can vary depending on the breed, age, and care of the sheep.
3	Karakul wool	1.28 - 1.38	The density of Karakul wool depends on the thickness and composition of the fiber.
4	Camel wool	1.20 - 1.30	The density of camel hair can vary depending on the type of camel and the quality of its hair.
5	Cotton fiber	1.50 - 1.55	The density of cotton fiber depends on moisture content and the type of fiber.

Notes:
The data in this table are averages, and the density of each fiber may vary depending on its type, sampling method, and measurement conditions. Density is understood as the mass of a unit volume of fiber. Rabbit, sheep, camel, and karakul wool consist of natural polymers (ceramics), which retain air well, therefore their density is low. Cotton fiber is composed of cellulose and has a higher density than wool.
Based on the table above, the advantages of Rabbit Wool (Hikol) can be analyzed as follows:
Low density: The density of rabbit wool (0.95 - 1.15 g/cm³) is much lower than that of other wool fibers (sheep, karakul, camel) and cotton fiber. This low density ensures the lightness of rabbit wool and the ability to retain a lot of air.
Thermal insulation properties: Low density is especially important for thermal insulation materials. Because air is an insulator that does not conduct heat well. Therefore, materials made from rabbit wool have high thermal insulation properties.
Lightness: Lightness is important in building materials. Thermal insulation materials made from rabbit wool do not add additional weight to building structures.
Economy: Low density also allows you to spend less raw materials in the production of the material. This reduces production costs.
The data in the table show that rabbit wool, in particular the Hikol breed of rabbit wool, is preferable to traditional materials for the production of thermal insulation materials due to its low density.

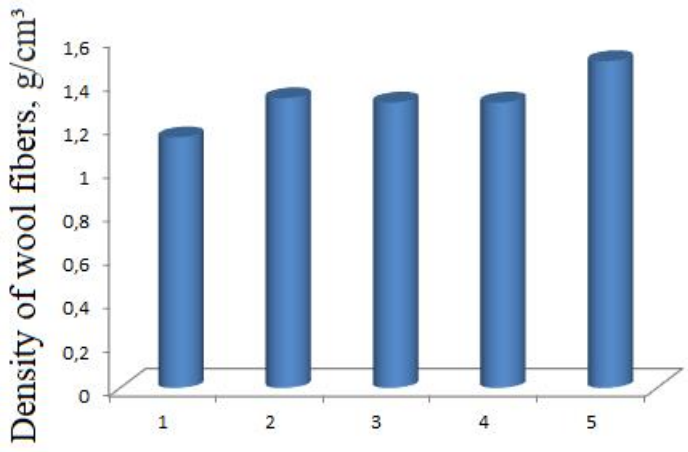

Figure 2. Density of different animal wool fibers.
1-rabbit wool, 2-sheep wool, 3-karakul wool, 4-camel wool, 5-cotton fiber
The tenacity of rabbit wool fibers is 14 cN/tex and the elongation at break is 40%. Due to the very thin and brittle nature of the fiber, this fiber is not usually used in fabric weaving. Can you measure these values for the remaining fibers and for each of the 4 fibers? They were given in a table. The low tenacity of rabbit wool can be overcome by using it in the textile industry in a mixture with other fibers [30]. However, it can be used as a thermal insulation layer in clothing.
Conclusion: The chemical composition of the Hikol rabbit wool was found to contain a high amount of keratin protein, which ensures its strength and durability. The physical properties of the wool, in particular its low thermal conductivity, allow it to be used as an excellent thermal insulation material. Microstructural analysis showed that there are many air-holding voids between the wool fibers, which further reduces thermal conductivity. Hikol rabbit wool is a renewable, environmentally friendly and sustainable resource. Wool generated in the rabbit industry can be recycled as agricultural waste, reducing the negative impact on the environment. This process also provides an opportunity to create an additional source of income for farmers and rural residents. Thermal insulation materials obtained from Hikol rabbit wool have a number of environmental and economic advantages over traditional materials (mineral cotton, expanded

polystyrene). Their production process consumes less energy, does not emit harmful waste to the environment, and is easy to dispose of. Economically, the costs of collecting, cleaning, and processing wool are relatively low, reducing the price of the finished product.

Thermal insulation materials made from Hikol rabbit wool have wide application in the construction sector. They can be used to protect walls, roofs and floors of buildings from heat. These materials can also be used in the industrial sector, for example, to protect refrigeration equipment from heat. Based on the results obtained, the following recommendations can be made: Increasing the number of Hikol rabbits in the rabbit breeding sector and increasing the volume of wool production; Improving the technologies for processing Hikol rabbit wool and obtaining thermal insulation materials from it; Using various additives and modification methods to improve the properties of these materials; Widely introducing thermal insulation materials based on Hikol rabbit wool in the construction sector and promoting their advantages. In conclusion, the wool of the Italian breed Hikol rabbit is a promising and effective source of thermal insulation materials. Its environmental friendliness, recyclability and excellent thermal insulation properties allow it to be used as an alternative to traditional materials. Future research and practical work in this area will help make the construction industry more sustainable and environmentally friendly.

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