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PROSPECTS FOR ALTERNATIVE USE SHEEP WOOL

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This article contains the results of the authors' review of the publicly available literature devoted to the problem of alternative (except for traditional textile) use of sheep wool in various areas of production. It reflects the decline in total wool production and purchase prices for it, as well as outlines the relevance for the development of the sheep industry of finding alternative ways to use it. It is shown that due to its specific physical and technical properties, wool is increasingly used as an environmentally friendly material for the manufacture of composite new building materials-heat and noise – insulating materials, plaster, bricks, concrete. It is also used as mulch and agrofibre substitutes in agricultural technologies for growing grain, vegetable crops, berries and sugar beet, as well as in Horticulture, Forestry and landscape gardening. At the same time, in new materials and technological processes made with the use of wool, heat and sound insulation and mechanical properties (building materials) are significantly improved, yield (crops) increases and the temperature and biological regime of the soil, its saturation with nitrogen, carbon and some minerals improves. Wool, as a natural product that is subject to the action of biodegradation processes, contributes to the greening of production and reducing its energy intensity.

Keywords: alternative use, sheep wool, building materials, energy and eco - efficiency.



ПЕРСПЕКТИВИ АЛЬТЕРНАТИВНОГО ВИКОРИСТАННЯ ОВЕЧОЇ ВОВНИ

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Дана стаття містить результати виконаного авторами огляду наявної у відкритому доступі літератури, що присвячена проблемі альтернативного (крім традиційного текстильного) використання овечої вовни в різних сферах виробництва. В ній відображено зниження загального виробництва вовни та закупівельних цін на неї, а також окреслено актуальність для розвитку галузі вівчарства пошуку альтернативних шляхів її використання. Показано, що завдяки своїм специфічним фізико-технічним властивостям, вовна все більше використовується в якості екологічно чистого матеріалу для виготовлення композиційних нових будівельних матеріалів – тепло- та шумоізолюючих матеріалів, штукатурки, цегли, бетону. Також знаходить застосування в якості мульчі та заміників агроволокна в агротехнологіях вирощування зернових, овочевих культур, ягід і цукрових буряків та в садівництві, лісовому і садово-ландшафтному господарстві. При цьому, у нових матеріалах та технологічних процесах, виконаних з використанням вовни, значно покращуються тепло- і звукоізоляційні та механічні властивості (будівельні матеріали), збільшується врожайність (сільськогосподарські культури) та покращується температурно-вологісний режим ґрунту, його насиченість азотом, вуглецем та деякими мінеральними речовинами. Вовна ж, як натуральний продукт, що підпадає дії процесів біодержадації, сприяє екологізації виробництва та зниженню його енергоємності.

Ключові слова: альтернативне використання, вовна овець, будівельні матеріали, енерго- та екоефективність.

Introduction. Sheep wool is a unique renewable natural product, which is a substitute raw material resource for the development of the textile industry. Low thermal conductivity, roll capacity, hygroscopicity, elasticity and and strength firmness – this is a complex of physical and technical properties that is inherent only in natural wool fibers. Due to these properties, sheep wool has acquired a variety of uses. In the structure of its world production, fine wool accounts for 40-45%, semi – fine wool – 25-30%, semi-coarse and coarse wool-30-35%. At the same time, 2/3 of its total volume is used for the manufacture of clothing, and 1/3 – for carpet, non-woven (felted) products and technical purposes. Total wool production in 2023 in the world amounted to 1 million tons. 746 thousand tons, and in the dynamics over the past 10 years, there is a decrease in this indicator by 305 thousand tons, or by 14.9 % (according to FAO statistics, 2023).



This state of production is primarily due to a decrease in purchase prices for unwashed and washed sheep wool, due to competition in the market from cheaper synthetic fibers. Over a ten-year period, these prices in one of the leading countries producing high – quality sheep wool – New Zealand-decreased by almost 1.6 times (from 3.1 to 1.97 thousand \$/ton), in Europe-by 2.5-5 times (Hungary, Poland, Germany). The price per ton of wool in Ukraine also decreased by 2.1 times. This situation encourages producers to change the specialization of the sheep industry to produce lamb and Lamb, as well as milk and other products. In this regard, there is an increasing interest in breeding sheep breeds that are characterized by a reduced ability to form runes and, as a rule, produce low-quality wool, which has a low purchase price and is not in demand in the textile industry. Along with this, the search for ways to reduce the cost of production of sheep products by reducing energy consumption when creating sheep breeding facilities has become relevant.

Authors (Berge, B., 2001; Korjenic A., Klarić S. et al., 2015) in their experimental studies give the main directions for improving the efficiency of the livestock complex. The researchers emphasize that sheep storage facilities don't have to be complex or expensive. Therefore, preference is given to the reconstruction of existing livestock premises in the direction of improving the technological efficiency and ergonomics of the main production processes, as well as ensuring appropriate microclimate conditions and comfortable keeping of animals. As an alternative to capital rooms for keeping sheep, light structures and awning shelters are considered. This is not only about reducing energy consumption and loss, but also about reducing the cost of construction or reconstruction through the use of natural and locally available materials, including the products of the sheep themselves, namely their wool. An important condition for creating livestock production facilities is their environmental friendliness – minimal impact on the deterioration of air and water quality, as well as soil cleanliness.

Against the background of the above - mentioned depreciation of wool, in the system of measures to improve the efficiency of sheep production, in addition to finding ways to reduce capital and current costs, there is also an urgent issue-expanding the range of its application in various fields. Therefore, the purpose of this publication was to study ways of alternative (except for the textile industry) use of sheep wool in other industries.

Materials and methods. The object of research was the directions and trends, as well as the effectiveness of using sheep wool in various production areas. The research was carried out by accumulating, analyzing and summarizing the data available in open publications on the efficiency and prospects of using sheep wool in various production areas. Systematization of primary information was carried out using bibliographic and source analysis.

Research results. In the context of preventing global environmental challenges, improving the ecology of building materials plays an important role. This problem is most widely covered in the book "The Ecology of Building Materials" (Berge B.,2001). From the point of view of ensuring sustainable development, it shows the feasibility of wider use of local environmentally friendly raw materials for the production of building materials, which are easily processed and restored. These include wood, straw, biological fibers, and sheep wool. At the same time, it is important that technologies with a low level of energy consumption are used in the process of processing it. According to the author, solving this problem requires scientific and intersectoral interaction. Therefore, manufacturers' interest in obtaining cheap new construction and thermal insulation materials of organic nature is spreading in the world.

According to korjenic A., Klarić I., Hadžić A. and Korjenic S. (2015) the construction industry accounts for up to 40% of CO₂ emissions and is characterized by



high energy intensity of production processes. Therefore, according to them, research aimed at finding alternative renewable natural building materials can significantly affect the reduction of these indicators.

In European countries, the importance of solving the problem of reducing environmental challenges associated with building materials is emphasized by the relevant directive - 2010/31/EC of the European Parliament and the European Council (of 19 May 2010). It sets out the requirements that the building energy efficiency certificate must contain information on the actual impact of heating and cooling on the building's energy needs, as well as on primary energy consumption and carbon dioxide emissions.

The use of wool waste as a new raw material in the construction industry, according to Tarring T., Sandvik K. (2000) is an excellent opportunity to create a closed economy model, as it reduces the need for non-renewable resources, reduces the carbon footprint, and is a resource-saving method for producing industrial components, which can also play a significant role in energy conservation and reducing environmental pollution.

Now, in order to effectively use wool as waste from agricultural production and its use in other production areas, Midolo G., Valenti F. (2024), an organizational model based on the Geographic Information System (GIS) is proposed for determining the location and amount of waste (sheep wool) and sustainable management of the use of these raw materials as a potential component of green building.

So, from the above-mentioned reports, it can be stated that a possible area of widespread alternative use of wool is the construction industry.

Among the promising areas for improving the energy efficiency of buildings, first of all, the issue of improving their thermal insulation characteristics through the use of new insulation materials is considered. So, Korjenic A.; Petráněk, V. et al. (2011) note that thermal insulators made of natural materials are likely to become an acceptable alternative to widely used boards made of various artificial materials (mineral wool, polystyrene or polyurethane), since they are quite competitive in their technical and technological characteristics. So Zach J., Korjenic A., Petráněk V. et al. (2012) propose to study sheep wool as an alternative thermal insulation biomaterial with good thermal and acoustic properties to improve building comfort and reduce carbon emissions. The use of this natural material in construction can also be useful for preserving human health.

The advantages of wool as a heat insulator are more clearly emphasized in the message of Doroudiani S. et Omidian H. (2010) that expanded polystyrene, which is now one of the most common thermal insulation materials in construction, poses serious problems for environmental safety and human health, as it has an extremely high tendency to burn and emits toxic fumes.

According to Korjenic A., Klarić I., Hadžić A. and Korjenic S. (2015), sheep wool, evaluated by hygrothermal modeling and ecological balance methods compared to mineral wool and calcium silicate, provides better physical, energy and environmental characteristics of the thermal insulation material. At the same time, only 5.4 kg of CO₂ emissions are generated per 1 M³ in the production of insulation from sheep wool, while for mineral wool this figure exceeds 135 kg.

Ahmed A., Qayoum A., Qayoom Mir F. (2019), also consider sheep and goat wool and horsehair (Mane) as possible environmentally and cost-effective insulation materials. At the same time, they note the best hygroscopic properties of sheep and goat hair over horsehair, which is due to the different structure and thickness of The compared fibers. Goat hair was the lowest in terms of thermal conductivity among the compared materials.



The results of tests of sheep wool indicate excellent performance of the material not only in the development of construction thermal insulation elements, but also for sound insulation.

According to Borlea (Mureşan) S. I., Tiuc A.-E., Nemeş O., Vermeşan H., Vasile O. (2020) materials obtained by simple hot pressing of wool are characterized by high sound – absorbing properties with significant acoustic absorption coefficients-more than 0.7 for the frequency range of 800 ÷ 3150 Hz, and according to these characteristics, sheep wool has comparable sound-absorbing properties to mineral wool or polyurethane foam.

According to Parlato M.C.M. and Porto S.M.C. (2020), the use of sheep wool as an alternative to insulation materials such as fiberglass, rock wool, polyurethane foam, polystyrene provides significant benefits for sustainable development, reducing production costs for the production of these materials and reducing environmental pollution.

Research by Polish scientists (Kicińska-Jakubowska A. et al., 2023) prove the high efficiency of multifunctional sound and thermal insulation materials from waste natural protein and lignocellulose fibers in accordance with the principles of bioeconomics. As natural materials, they studied the low-quality wool of local coarse-wool sheep and a mixture of Bast fiber waste formed as a result of the manufacture of ropes and ropes, which were connected in various proportions by needle punching in the form of technical mats. An increase in the proportion of wool over Bast fibers helped to improve the thermal insulation properties of products, while a large proportion of Bast fibers gave products better barrier sound protection properties.

Also a number of scientists (Vasina M. et al., 2024) indicates the possibility of using sheep wool in polymer composites in the manufacture of materials with noise - and vibration-absorbing and electrical insulation properties. According to their data, the addition of wool fibers to epoxy, polyurethane and polyester resins from 3 to 5% by weight significantly improved their physical qualities.

In addition to the traditional use of wool for the manufacture of Textiles, Starkova O., Sabalina A, Voikiva V. and Osite A. (2022) emphasize the possibilities of its application in the process of reinforcing polymer composites for 3D printing.

Pederneiras C.M., Veiga R. and Brito J. (2019) focus on the feasibility of using sheep wool for reinforcing mortars and, in particular, to increase the resistance of plasters to cracking. According to their data, the use of cement and cement-lime mixture as binders with the inclusion of 10% and 20% (by volume) wool fibers with a length of 1.5 cm and 3.0 cm increased the plasticity of mortars, and improved their mechanical properties.

See Also Atbir A., Khabbazi A., Cherkaoui M. et al. (2023), investigating a new thermal insulation material - a porous plaster reinforced with a multilayer thread base made of sheep wool, note an increase in flexural strength in this material from 30% to 74% with a decrease in compressive strength from 48% to 71%. At the same time, the density of the material decreased with increasing length of wool fibers.

In search of sustainable and environmentally friendly insulation materials, Urdanpilleta M., Leceta I., Martín-Garín A. et al. (2025) conducted a study of biocomposites from sheep's wool included in a polymer matrix that bound soy protein by sublimation drying with 7, 10, 15 and 20% by weight of wool. To protect these biocomposites from insects, coffee grounds were added to the formulation. The new insulation material was not inferior in thermal conductivity to other natural analogues and showed high protective properties against keratophagous insects, especially against carpet beetles.



In addition to the above-mentioned building materials, sheep wool is also used in the production of concrete.

Thus, the positive effect on the physical and mechanical properties of concrete and sheep wool composites is noted in their publications Fantilli A. P., Sicardi S., Dotti F. (2015) and Dénes O., Florea I., Manea D.L. (2019).

Research By Alyousef R., Alabduljabbar H., Mohammadhosseini H. et al. (2020) and Alyousef R., Mohammadhosseini H., Ebid A.A.K., Alabduljabbar H. (2022) also found that adding up to 6% of sheep wool fibers with a length of 70 mm in the production of fiber concrete reduced the shrinkage rates of fresh concrete, while reducing its compressive strength. However, with a certain period of time, the tensile and flexural strength of fiber concrete increased, which increased its ductility and ability to absorb energy. The microstructure of concrete was characterized by a decrease in the size of cavities. In addition, the addition of 2 % (in volume fractions) of fibers to Portland cement reduced the sorption coefficient of the concrete composite and the depth of penetration of chlorides into the mixtures.

Research By Abdul Awal A.S.M., Mohammadhosseini H. (2016). they prove that not only natural sheep wool, but also carpet thread waste together with palm oil ash can be effectively used in the production of concrete. Its technical characteristics-high tensile and flexural strength (increased ductility), lower porosity, higher energy absorption capacity ensures not only high quality as a building material, but also increases the environmental cleanliness of production.

In addition to facing heat and noise insulation materials and plasters, concrete production, natural sheep wool finds its application in the manufacture of bricks.

El Wardi F.Z., Ladouy S., Khabbazi A. et al. (2021) report that in the process of manufacturing unburned clay bricks, light composite materials with lower thermal conductivity and higher compressive and flexural strength were obtained by adding used cork pellets and quicklime and sheep wool fibers to it in certain proportions than bricks made using traditional technology. Clay-cork blocks reinforced with 30% lime content and 2% sheep wool fibers had the highest thermomechanical indicators. They had a low volume density of 583 kg/m³ and were characterized by increased thermal and mechanical qualities.

Similar changes in the physical and mechanical properties of bricks made of clay of various compositions were noted in their research by Galán-Marín C., Rivera-Gómez C., Petric-Gray J. (2010). According to them, sheep wool added in optimal proportions to its composition minimized shrinkage, reduced curing time and increased the compressive and flexural strength of the finished product.

Parlato M.C.M., Cuomo M., Porto S.M.C.(2022). it is also proposed to use sheep wool fibers as reinforcing components to clay in the manufacture of bricks. At the same time, they note an increase in tensile strength, ductility, impact resistance, viscosity and a decrease in shrinkage during brick drying.

According to Atbir A., Taibi M., Aouan B. et al. (2023), unburned solid bricks based on white and red clay, made with the addition of sheep wool, have fairly high thermal and mechanical characteristics and are characterized by a light specific gravity. At the same time, the positive effect of wool admixture was significant on the mechanical behavior of the developed materials after 90 days - in terms of flexural strength from 18 to 56% for white clay and from 8 to 29% for red clay. These mechanical characteristics were accompanied by an increase in thermal conductivity from 4 to 41% for white and from 6 to 39% for ore clay fractions.

Wool, due to its unique physical and technical properties, also finds its application as components of mulch in the cultivation of various agricultural crops. Thanks to it, it is



possible to control thermoregulatory processes and soil moisture, as well as enrich it with nitrogen and other substances formed during the biodegradation of wool.

In this regard, Camilli F., Focacci M., Dal Prà A. et al. (2025) note that sheep wool has great potential for use in agricultural production, as it has a high content of nitrogen, carbon, sulfur and is characterized by a high ability to absorb water and retain moisture. These properties help preserve the carbon content of the soil and increase its fertility, as well as reduce the risk of water pollution due to the gradual decomposition and release of nitrogen.

According to the research results of Gabryś T., Fryczkowska B. (2022), the use of sheep's wool by mixing it evenly with the soil when growing indoor plants *Chlorophytum comosum* better provided them with water and increased root system growth. At the same time, individual fibers dispersed in the soil decomposed better than fibers that were arranged in a layer at the bottom of the pot.

In the publication Broda J., Gawłowski A., Rom M. et al. (2024) reported a comparative evaluation of the use of mountain sheep wool, straw, and bark as mulch in strawberry cultivation. They experimentally proved the best thermoregulatory properties of wool compared to other materials. Wool mulch minimized fluctuations between day and night soil temperatures (fluctuations did not exceed 2-3 ° C in hot weather, which is almost five times less than in the control area and twice as much as in straw and bark mulch. In addition, the wool retained more moisture after precipitation (the mass of water retained by the wool is several times higher than its own mass). Wool, as a substance for mulch, had a much longer period of biological decomposition than bark and especially straw, and therefore can be used for a longer period. These advantages of wool contributed to an increase in Strawberry yield.

By the same researchers (Broda, J., Gawłowski, A., Rom, M., & Kobiela-Mendrek, K., 2023) it was found that during the growing season, nitrogen compounds gradually enter the soil, and the nitrogen content in it clearly correlates with an increase in the processes of degradation of sheep wool introduced into it. The released wool nitrogen had a positive effect on wheat growth at different stages of its development, which was observed in the form of increased tillering, an increase in the height of stems and provided an increase in yield.

In the publication Taskin M. B. (2024) it is reported that the introduction of sheep wool and wool hydrolysate into the soil contributed to an increase in the yield of both stem mass (by 40.2% and 52.1%) and sugar beet root crops (by 4.59% and 7.61%). At the same time, an increase in the concentration of nitrogen, calcium, magnesium and phosphorus in the stems of plants was found, both with the use of wool and its hydrolysate, and the sugar content of beets from the specified technological method of their cultivation did not worsen.

Studying the interaction in the plant – soil –micro-organisms chain, Juhos K., Papdi E., Kovács F. et al. (2023) when growing bell peppers under laboratory conditions, it was found that the effect of sheep's wool content in various soils (sand, loam, peat) on biomass yields was significantly higher with less irrigation than when using agrofibre and straw. The microbiological activity of the soil was also higher than the introduction of wool, due to its better water retention capacity, which positively affected the yield of pepper.

Similar studies on pepper cultivation (*Capsicum annum* L.) was also performed on soils of different composition – Sandy with a low content of organic substances and coarse loams with a high moisture capacity, Papdi E., Veres A., Kovács F., Juhos K. (2022). They found that all irrigated areas where wool mulch was used were characterized



by a higher carbon content in the soil, and loamy areas – and beta-glucosidase activity. The use of wool mulch contributed to the formation of a higher yield.

To study the characteristics of tree growth and development, as well as the yield and quality of gitea m plum fruits. A., Borza I.M., Domuta C.G. et al. (2024) conducted an experiment on the use of sheep wool mulch and conditioner for soil containing corn starch. They found an increase against the control of plum yield by 27% in areas where wool mulch was used and by 37% where a combination of wool and soil conditioner was used, against the background of an increase to 48.9% by weight and from 5 to 19% by fruit size.

As an alternative to vegetable mats made from coconut fibers, Herfort S., Pflanz K., Larsen M.-S. et al. (2023) evaluated similar products with the inclusion of different amounts of sheep wool in their composition when growing perennials for garden and landscape design. Their studies revealed a 21-38-fold higher content of nitrogen in the products and 1.5 - 1.8 – fold higher content of water. Perennial plants that were grown using combined coconut-wool mats were characterized by better development and yield.

In addition to the use of wool as a mulch for the soil in the cultivation of agricultural crops, it also finds its application in forestry.

The effectiveness of using a repellent made from sheep's wool to protect young forest stands from damage to the tops of their shoots by deer was tested in Bernacka H studies., Świącicka, N., Naworska N. (2015). In forest stands that were not covered with wool repellent, the area of damage caused by deer increased more than 4 times over three years of the experiment. In this regard, the researchers concluded that it is advisable to use sheep's wool to protect forest stands, as an alternative to their treatment with harmful chemicals.

Another area of application of sheep wool, according to Szatkowski P., Tadla A., Flis Z. et al. (2022), is the production of thermally insulated, eco-friendly packaging, which is characterized by complete biological theft. The experimental packaging produced by them by injection molding was not inferior in thermal insulation characteristics to its expanded polystyrene analogues, and the introduction of wool fibers accelerated the process of its biodegradation in laboratory-modeled natural conditions.

Discussion. Analysis of the state of wool production and the dynamics of purchase prices for it in the world and in Ukraine indicates a decrease in both the total volume of its production and demand for it. This is one of the reasons for finding alternative production areas for this natural, renewable product than the textile industry. Research by many scientists also shows increased attention to the problem associated with the use of sheep's wool waste to solve environmental problems (Torrington T., Sandvik K., 2000; Parlato M. C.M. and Porto S.M.C. , 2020; Parlato M.C.M., Porto S.M.C., Valenti F., 2022; Juhos K., Papdi E., Kovács F. et al., 2023; Midolo G., Valenti F., 2024).

According to a number of publications, there is an increase in research aimed at evaluating the effectiveness of using sheep's wool in the manufacture of new building materials – heat and noise insulation, plaster, brick, concrete (El Wardi F.Z., Ladouy S., Khabbazi A. et al., 2021; Alyousef R., Alabduljabbar H., Mohammadhosseini H. et al., 2020 and Alyousef R. , Mohammadhosseini H., Ebid A.A.K., Alabduljabbar H., 2022) , as well as studies related to the use of wool in agricultural technologies and forestry in the cultivation of various crops (Camilli F., Focacci M., Dal Prà A. et al., 2025).

At the same time, Corscadden, K. W., Biggs, J. N., & Stiles, D. K. (2014) note that the choice of materials in production has the nature of trade-offs between their characteristics, properties, Environmental Impact, Sustainability, availability, and cost-effectiveness. The desire to integrate more bio-products and natural and renewable resources primarily in the construction industry is now associated with sheep wool.



This approach, according to Jannat N., Hussien A., Abdullah B. (2020), reduces energy consumption in construction and other industries, and promotes efficient waste management.

Currently, major projects are already being implemented to create industrial enterprises aimed at solving environmental problems related to the use of wool. So, according to Al-Malah K.M., Al-Khalafat M.R., Al-Zayadeen N.A. et al. (2025) the construction of a processing plant in Jordan for more than 6.5 thousand tons of wool per year (production of 114.8 thousand m³ of insulation boards) is a profitable project with a return on investment within one year.

Conclusions.

1. sheep wool, in addition to its traditional use in textile production, is finding an increasingly wide alternative application in various production areas.

2. due to its unique physical and technical properties and the ability to biodegrade, its use is widespread in the construction and agricultural sectors, in the production of packaging materials, and in the manufacture of products using 3 D technologies.

3. for many countries of the world and Ukraine, the development of modern technologies and assessment of the economic and environmental efficiency of alternative applications of sheep wool in the field of manufacturing new materials, construction, agricultural production, forestry is a promising urgent task.

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