Chapter 3

DEVELOPMENT OF SCIENTIFIC FOUNDATIONS FOR OBTAINING BAST FIBER FILLERS FOR THE PRODUCTION OF TECHNICAL TEXTILES

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INTRODUCTION

Ukraine's accession to the WTO has intensified the competitive struggle for the Ukrainian market, which objectively requires constant improvement of the quality and expansion of the range of products produced, thanks to the use of environmentally friendly materials and the development of innovative technologies for the production of technical textiles of various functional purposes. The production of technical textiles is a subsector of the textile industry, which is developing most dynamically in the leading countries of the world. Currently, the scope of application of technical textiles covers more than a hundred functional objects, and new areas and objects arise on the basis of a combination of inventive activity and marketing methodology based on the study of the needs of society. This is what gave impetus to the creation of a new range of household goods. One of the main areas of use of innovative products is the production of non-woven materials of such types as fibrous webs, batting and geotextile materials.

Currently, the only source of environmentally friendly raw materials for the production of technical textiles in Ukraine is fiber from bast crops. However, there is currently no data on scientific research and production tests in the field of using bast fibers for the production of technical textiles, as well as on the physical and mechanical characteristics of fibers suitable for the production of technical textiles. Therefore, the issue of developing innovative technologies for the production of technical textiles of various functional purposes based on the use of oil flax fiber is particularly relevant. The growing demand in Ukraine for technical textiles can be satisfied if domestic raw materials are used for its production – oil flax fiber, which in terms of physical and mechanical characteristics will meet the requirements of state standards for technical products.

Based on the above, we can conclude that the in-depth processing of oil flax straw stems in order to obtain bast, and subsequently fibers, with the necessary physical and mechanical indicators for the production of

environmentally friendly organic technical textiles of various functional purposes is an important task of the flax processing industry.

1. Global and domestic experience in the production of technical textiles and its application areas

In recent years, technical textiles have gained great popularity in the world due to the expansion of their range. The production of new textile products is associated with the use of advanced technologies. The main producers of technical textiles in the world are developed countries with powerful industry, high technologies and investments in innovation [1]. Below is a list of the main countries producing technical textiles:

1. China. The world's largest manufacturer of textile products, including technical textiles (nonwovens, filter fabrics, geotextiles). Large-scale production, state support, innovations in biodegradable textiles.

2. Germany. The leader in Europe in the production of high-tech textiles. Strong engineering base: technical textiles for the automotive, medical, construction industries.

3. USA. Powerful technical textiles industry: military textiles, medical materials, aerospace composites. Developed research centers (e.g. MIT, NCSU).

4. India. One of the largest exporters of nonwovens, jute, geotextiles. State support programs for the technical textiles industry.

5. Japan. Focus on innovative and functional fibers (fire-resistant, antibacterial, smart fabrics). High quality products for medicine, electronics, cars.

6. South Korea. Manufacturer of smart textiles, materials for electronics and sports. Partner of many international brands.

7. Italy. Well-known production of technical textiles for fashion, sports and industry. Strong positions in the field of textile design and functionality.

Table 1 shows the main manufacturers of technical textiles in the world and the main types of their products.

Table 2 lists the leading companies producing technical textiles in the world.

[1] Gorach O., Dombrovska O., Tikhosova A. Development of resource-saving technologies for obtaining composite materials based on the use of oilseed flax fibers *Inmateh – agricultural engineering*, 2021, Vol. 65(3). P. 275-282. https://doi.org/10.35633/inmateh-65-29

Table 1

Productions of technical textiles in the world

Country	Types of technical textiles
China	Geotextiles, construction, agricultural, filter materials, nonwoven textiles
Germany	Automotive, medical, construction, functional fabrics, protective textiles
USA	Military textiles, medical, composites, aerospace textiles, sports
India	Geotextiles, agrotextiles, jute technical textiles, nonwoven textiles
Japan	Smart textiles, fire-resistant and antibacterial fabrics, electronic fibers
South Korea	Sports, electronic textiles, smart fabrics, lightweight composites
Italy	Fashion + technical functionality (sports, protection), construction textiles, technical accessories

Table 2

Leading companies producing technical textiles

Country of manufacture	Company name
China	China National Textile Group, Tongkun Group, Zhejiang Hailide New Material
Germany	Freudenberg Group, Aunde Group, Sandler AG, Schoeller Textil
USA	DuPont, Milliken & Company, Berry Global, TenCate Protective Fabrics
India	SRF Limited, Garware Technical Fibres, Alok Industries, Welspun
Japan	Toray Industries, Teijin Limited, Asahi Kasei, Unitika Ltd
South Korea	Hyosung Advanced Materials, Kolon Industries, KOLON Glotech
Italy	Marzotto Group, RadiciGroup, Beaulieu Fibres International, Saati Group

Technical textile companies engaged in the production of fibers: polyester, aramids, fiberglass, both technical textiles and medical fabrics, filter materials, geotextiles, protective clothing.

Currently, the scope of application of technical textiles covers more than a hundred functional objects, and new areas and objects arise on the basis of a combination of inventive activity and marketing methodology based on the study of the needs of society. This is what gave impetus to the creation of a new range of household products. One of the main areas of use of innovative products is the manufacture of non-woven materials of such types as fibrous fabrics, batting and geotextiles [2].

[2] Gorach O., Dombrovska O., Tikhosova A. Scientific development of innovative technologies of obtaining composite materials from of oilseed flax fibers. *Vlákna a textil*, 2021, Vol. 28(4). P. 25-30. http://vat.ft.tul.cz/2021/4/VaT_2021_4_4.pdf

Fiber cloths are pressed layers of fibers used for building insulation, protection against solar radiation, snow drifts, in landscape design, for strengthening slopes.

Batting is narrow strips of pressed fibers, thinner than cloths, used during construction as heat, vibration, sound insulation, wiping materials, etc.

Geotextiles are composite materials, non-woven fabrics are used for reinforcement. They are used for:

– construction and repair of highways and railways;
– temporary roads, access roads;
– major roads, runways, airport runways;
– warehouses, parking lots;
– drainage of any type – trench, layer, gallery, vertical;
– protection against erosion of slopes, banks, embankments, and hydraulic structures;
– construction of sports fields, artificial landscapes, swimming pools, sidewalks, lawns, flower beds, coastal fortification, soil protection from erosion, drainage.

The use of such products for the manufacture of complex technical objects allows solving various target tasks, achieving high operational indicators of these objects (accuracy, safety, etc.). In Ukraine, technical textiles are produced by both large enterprises and specialized factories operating in the defense, medical, agricultural and industrial sectors [3]. Table 3 lists the main manufacturers of technical textiles in Ukraine.

Table 3

Main manufacturers of technical textiles in Ukraine

Enterprise	Type of technical textiles
Textreid	Nonwoven textiles, geotextiles, materials for agriculture and construction
Kyiv	Technical fabrics, including for agricultural machinery
Bar Mechanical Plant	Fire-resistant, water-repellent and protective fabrics (military orders)
Vinnytsia Region	Technical fabrics, reinforcing materials
Balakliysk Industrial Complex "Mayak"	Textiles for the furniture and automotive industries
Kharkiv Region	Geotextiles, reinforcing materials for construction
Cherkasy Silk Mill	Medical, sanitary, packaging textiles

[3] Чурсіна Л.А., Тіхосова Г.А., Горач О.О., Янюк Т.І. Наукові основи комплексної переробки льону олійного друк. *Монографія.* Херсон: Олді-плюс, 2011. 356 с. https://surl.gd/zkdukm

Main areas of application in Ukraine:
– construction (geotextile, reinforcement);
– agricultural sector (agrofiber, protective coatings);
– medicine (surgical wipes, filters);
– military (protective and fire-resistant fabrics);
– furniture and automotive industry.

Today, in Ukraine, technical textiles are made only from expensive imported synthetic raw materials, and the production of technical textiles from natural fibers is almost completely absent, mainly due to the lack of its own raw material base.

Advanced processing of oil flax straw stalks to obtain bast, and subsequently fiber, with the necessary physical and mechanical indicators for the production of environmentally friendly organic technical textiles for various functional purposes is an important task of the flax processing industry [4]. Leading scientists have proven that flax fiber is suitable for the production of technical textiles for various purposes.

Analysis of the development of the technical textile sector in the world indicates its high profitability and sustainability due to the wide range of products and the variety of directions of their application in various industries. The development of the technical textile sector in the world is dynamic and strategically important, as it covers the defense, construction, transport, medicine and environmental industries. The main directions and factors of development are the growth of demand for use in the automotive industry, aviation, sports, medicine, and the agricultural sector. Nonwovens have become widely used due to their ease of manufacture and low cost. One of the current directions is the production of technical textiles from natural fibers: flax, jute, hemp and other biodegradable fibers. The creation of smart textiles is also actively developing, namely the introduction of conductive fibers, sensors, and fabrics with variable properties. As well as the introduction of resource-saving technologies, the use of secondary raw materials and environmentally friendly production technologies.

Factors contributing to development include investments in research and innovation, support for government programs, especially in the EU, China, India, global climate change, which requires new materials for protection, filtration and agriculture, demand for protective textiles after the COVID-19 pandemic and due to geopolitical instability. The main areas of development of technical textile production: geotextiles – for infrastructure, road reinforcement, soil protection; medical textiles – surgical fabrics, antibacterial, sterile materials; agrofiber – for greenhouses, mulching, plant

[4] Gorach O., Dombrovska O., Tikhosova A. Development of resource-saving technologies for obtaining composite materials based on the use of oilseed flax fibers *Inmateh – agricultural engineering*, 2021, Vol. 65(3). P. 275-282. https://doi.org/10.35633/inmateh-65-29

protection; protective and military textiles – fire-resistant, bulletproof, camouflage fabrics; composite materials – reinforcing fibers for aviation, transport, construction [5].

A study of the main trends in the development of technical textile production in leading countries of the world allows us to conclude that today one of the most successful and financially attractive industries in Ukraine can also be the production of technical textiles, for the production of which it is possible to use domestic annually renewable raw materials – oil flax.

Ukrainian manufacturers should study in detail the experience of Asian and Eastern European countries, which are now actively entering this market sector. First of all, this applies to China, but especially to South Korea, where the government is increasing funding for research and development in the above-mentioned area and plans to invest in the production infrastructure of the industry.

The structure of consumption of technical textiles in the world depends on the field of application. It is consumed most of all in industry, transport, medicine and construction [6]. Table 4 shows the general structure of consumption of technical textiles.

Table 4

Structure of consumption of technical textiles in the world, %

Application field	Share, %
Transport (auto, aviation)	22–25
Construction and geotextiles	15–18
Medicine and hygiene	12–15
Agriculture (agrotextiles)	8–10
Protective/Military Textiles	7–9
Industrial Filters, Technical Fabrics	10–12
Home appliances, sports, furniture	8–10
Other areas	5–7%

[5] Nguyen T.T, Indraratna B. Natural fibre for geotechnical applications: concepts, achievements and challenges. *Sustainability*, 2023, Vol. 15(11), Article #8603. https://doi.org/10.3390/su15118603

[6] Anusudha V., Sunitha V., Mathew S. Performance of coir geotextile reinforced subgrade for low volume roads. *Int J Pavement Res Technol*, 2021, Vol. 14. P. 213-221 https://doi.org/10.1007/s42947-020-0325-4

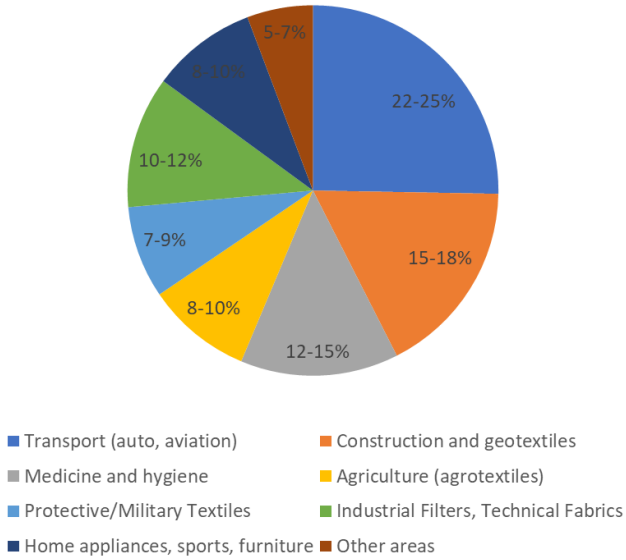

Fig. 1. Share of technical textile production in the world

Due to the projected growth in demand for technical textiles, the problem of finding raw materials for the manufacture of these products is acute. Currently, the main raw materials for the production of technical textiles are synthetic fibers, the share of which is 77%, and the share of cotton in technical materials is constantly decreasing.

In our opinion, the use of synthetic fibers in the manufacture of technical textiles for clothing, footwear, household needs and medical purposes is inappropriate, but on the contrary, for this type of products it is necessary to use environmentally friendly raw materials from natural fibers. The analysis of the technical textile market allows us to conclude that such product groups as agro-, geo-, construction, protective, automotive, medical, packaging textiles, filtering and sorption materials, which are in greatest demand among domestic consumers, can be produced from natural raw materials, namely using annually renewable oilseed flax fiber [7].

Ukraine's accession to the WTO has intensified the competitive struggle for the Ukrainian market, which objectively requires constant improvement of quality and expansion of the range of products produced through the use

[7] Pervaiz A., Azam F., Ahmad A., Ahmad F., Ahmad Sh., Ullah T., Nawab Ya., Shaker K. An Investigation of Static and Dynamic Mechanical Properties of Eco-Friendly Textile PLA Composites Reinforced by Flax Woven Fabrics. *International Journal of Polymer Science*, 2024, Vol. 1, Article #2821777. https://doi.org/10.1155/ijps/2821777

of environmentally friendly materials and the development of innovative technologies for the production of technical textiles for various functional purposes.

The main area of application of flax fiber abroad is the reinforcement of composite polymer materials. Thus, flax fiber is actively used abroad for the reinforcement of composite polymer materials (CPM), especially in industries where environmental friendliness, lightness and mechanical strength are important. The use of flax fiber for the reinforcement of CPM abroad in the automotive industry for the production of door panels, trim, trunks. For example, such enterprises as BMW, Mercedes-Benz, Audi use natural fiber (flax, jute) to reduce weight and improve environmental performance. Also, use in aviation to create lightweight interior parts of high-strength aircraft. Widely used in construction for reinforcing panels, as a heat-insulating material. Known areas of use of flax fiber for reinforcing composite polymer materials in the production of bicycle bodies, skis, skateboards, boats. For example, natural reinforced composites (NFC) are used in tennis rackets, surfboards. In the production of furniture and interior design, natural fibers are used for reinforcing decorative panels, lightweight seats, partitions. The main reasons and advantages of using flax fiber in composites include: weight reduction, high impact resistance, biodegradability, low cost compared to carbon or fiberglass fibers, and renewable resources.

Reinforcement of composite materials can be carried out with oriented or unoriented (entangled) fibers and nonwovens, yarns or even fabrics derived from them. If a nonwoven or fabric is used, the composite is formed in the form of a sandwich or pressed, located inside a layer, for example, polypropylene. This results in a very strong, unbreakable structural material. The fibers or bast are inside the polypropylene, that is, they are protected from the environment and are not subject to biological destruction [8].

Bast fiber material can be used for reinforcing structural polymeric materials not only in the form of a pre-formed nonwoven material, but also in the form of a mixture with a heated polymer, and is obtained in the processes of casting, extrusion or pressing. Glass fiber, used in our time in composite polymeric materials, is replaced by flax fiber, which makes them cheaper, less dangerous to manufacture, and easier to process. In addition, products that contain bast fibers, rather than glass fiber, are lighter and less brittle.

[8] Umair M., Ullah T., Nawab Y. 3D Natural Fiber Reinforced Composites: In book: *Natural Fibers to Composites. Engineering Materials*. Editors: Nawab Y., Saouab A., Imad A., Shaker K. Springer Nature Switzerland AG, 2023. P. 41-78. https://doi.org/10.1007/978-3-031-20597-2

A comparative characteristic of the quality indicators of natural fibers, which are most often used for reinforcing composite materials, is given in table 5.

Table 5

Characteristics of the quality indicators of the main natural fibers

Fiber	Tensile strength (MPa)	Elastic modulus (GPa)	Elongation at break (%)	Density (g/cm³)
Flax	500–900	50–70	2.7–3.2	1.4–1.5
Jute	300–800	10–30	1.5–1.8	1.3–1.5
Kenaf	220–930	14–60	1.5–2.0	~1.4
Hemp	550–900	70	1.6–1.8	1.4–1.5
Sisal	400–700	9–22	2.0–3.0	~1.5
Rami	400–950	40–80	1.5–2.0	~1.5
Coconut fiber	100–200	2–6	to 30	1.2–1.4

Analyzing the data presented in Table 5, we can conclude that flax, hemp and ramie have the best strength-to-density ratio, which makes them ideal for lightweight composites. Jute and sisal are cheaper, but less durable – suitable for structures with low loads. Coconut fiber has the lowest strength, but it absorbs shock well and is used for sound-absorbing and protective layers [9].

Analyzing the world experience of using flax fibers to obtain reinforced materials, we can conclude that oil flax fiber, having appropriate physical and mechanical characteristics, can be widely used in the automotive industry for the production of composite materials.

Composite materials reinforced with bast fibers are now used not only in the automotive industry, but also for the production of window frames. It should be noted that to prevent fire, they have a coating of polyacrylic plastic and fast-drying fixatives.

An important area of use of oil flax fiber is the production of nonwoven materials. Oil flax fiber is used in the world for the production of nonwoven materials. The use of oil flax fiber in the production of nonwoven materials is used as an agricultural fiber – mulching coatings, greenhouse shelters, insulation – eco-insulation in construction, automotive industry – noise insulation, seat linings, panels, furniture industry – fillers, substrates, filtration materials – air and water filters, as a packaging material – biodegradable substrates, transport inserts.

Thus, the use of oil flax fiber for the production of nonwoven materials is an important area of use. The main advantages include the fact that the fiber is an annually renewable resource, biodegradable and environmentally friendly, has

[9] Nitish K., Ramesh K., Surender S. Effective utilization of natural fibres (coir and jute) for sustainable low-volume rural road construction – A critical review. *Constr Build Mater*, 2022, Vol. 347, Article #128606. https://doi.org/10.1016/j.conbu ildmat.2022.128606

high sound and heat insulation properties, and has a lower impact on the environment compared to synthetic fibers. Many countries have accumulated extensive experience in the production of nonwovens from various fibrous wastes and low-grade long flax fiber. The production of nonwovens from long flax fiber involves the use of waste from the spinning process and short fiber after processing on the fiber-separating machine FSM-1 [10].

Unfortunately, Ukraine has not developed a technology for the production of nonwoven materials from oil flax fiber. However, the experience of scientists from different countries in using oil flax fiber for the production of nonwoven materials can be used at domestic enterprises. Scientists from the German Institute for Agricultural Construction and the Federal Center for Agricultural Research (L. Murphy, X. Bering, X. Wieland) studied the thermal insulation properties of nonwoven materials of different densities obtained from different materials (fiberglass, fine and coarse bast fibers). The results of the studies show that the thermal insulation properties of fabrics obtained from different raw materials differ significantly. If fabrics made of fine muslin or even chemically treated flax fiber are close in thermal conductivity to fabrics made of glass wool, then fabrics made of coarse fibers provide the necessary thermal insulation only with their high density. At the same time, in the low density range (10-20 kg/m^3), the difference between the thermal insulation properties of different materials is quite significant, and after 35 kg/m3 this difference becomes completely insignificant. Glass wool sheets will have a thermal conductivity of 0.05 W/(m K) at a density of 10 kg/m^3, and coarse bast fibers – only at 25-40 kg/m^3.

Therefore, with an increase in the density of non-woven materials, their thermal conductivity decreases. Technical textiles are usually made from chemical fibers such as viscose, polyester, polyamide, polypropylene, etc. The proportion of natural fibers such as linen, jute, coconut, cotton, wool used in the manufacture of these materials does not exceed 23% [11].

Based on the analysis of world experience in the use of technical textiles, it can be concluded that recently the production of textile products in the world has been developing rapidly and is characterized by investment attractiveness and rapid payback of costs. Technical textiles have gained great popularity due to the expansion of the range and areas of application, the emergence of the latest progressive methods and technologies of production,

[10] Chand N., Fahim M. Tribology of Natural Fiber Polymer Composites (Woodhead Publishing Series in Composites Science and Engineering) (Second Edition). Woodhead Publishing, 2020. 240 p.

[11] Горач О.О., Домбровська О.П., Чурсіна Л.А. Інноваційні напрями використання насіння льону олійного та екологічна безпека харчової продукції. *Колективна монографія:* Формування нової парадигми розвитку агропромислового сектору в XXI ст., Т. 2. Львів-Торунь: Ліга-Прес, 2021. С. 593-619. https://doi.org/10.30890/2709-2313.2023-23-01

the use of new types of raw materials. The main areas of application of technical textiles are: road and railway construction, landscape design, agriculture, hydraulic structures, laying tunnels and pipelines, protection of underground parts of residential and industrial buildings, land restoration after hostilities, etc.

In Ukraine, the production of technical textiles from natural fibers is almost completely absent, mainly due to the lack of its own raw material base. However, it should be noted that our country has great potential for the production of organic technical textiles from cheap cellulose-containing raw materials – oil flax.

Therefore, the development of domestic technologies for advanced processing of oil flax straw stalks, the determination of rational technological parameters and modes of their processing in order to obtain flax fibers with the necessary quality indicators suitable for the production of organic technical textiles for various functional purposes, is an urgent scientific and technical problem.

2. Analysis of modern technologies for producing technical textiles at domestic and foreign enterprises

The global market for technical textiles is actively developing in the following main areas:

- Medtech Medical bandages, implants, masks, surgical textiles;
- Mobiltech Materials for cars: seats, air cushions;
- Protech Protective clothing, special uniforms, fire-resistant fabrics;
- Buildtech Geotextiles, insulation, reinforcement of structures;
- Sportech Textiles for sportswear, equipment;
- Agrotech Nonwovens for greenhouses, mulching.

The main areas are the production of green textiles, as the demand for environmentally friendly, recyclable or biodegradable materials is growing. Also the production of smart textiles, for example in the production of sports and medical clothing, the use in nanotechnology to improve filtration, water repellency, antibacterial properties [12].

Based on the world experience in the production and use of technical textiles using natural fibers, it can be concluded that in Ukraine the prospects for the development of innovative technologies for the production of technical textiles of various functional purposes, as a subsector of light industry, are associated, first of all, with the use of oil flax fiber. The dynamics of the sown areas for oil flax in Ukraine over the past 15 years has shown significant fluctuations, due to both economic and geopolitical factors.

[12] Ahrari M., Karahan M., Karahan N. Competitiveness Factors in Textiles and Composites Industry and Transformation into Value-Added Products. *Recent Journal*, 2023, Vol. 24. P. 132–141. https://doi.org/10.31926/recent.2023.70.132

Growing oil flax is cheaper compared to sunflower, which makes it attractive for agricultural producers. Oil flax is an export-oriented oil crop, with the main sales markets in Europe. The crop adapts well to various soil and climatic conditions of Ukraine, which allows it to be grown in many regions. In general, oil flax remains a promising niche crop in Ukraine, with the potential to expand the sown areas and increase production in conditions of stabilization of the situation in the country [13].

The experience of using flax seeds, straw, hulls and fiber to create environmentally friendly products is quite promising and is already being actively implemented in a number of countries. Although flax is traditionally grown mainly for its seeds, its by-products (straw, hulls, fiber) are becoming increasingly important in the context of sustainable development, green economy and biotechnology.

Flax seeds are used in the food industry as a source of linseed oil with a high content of omega-3 fatty acids. It is widely used in the production of cosmetics and pharmacy, for example in oils, creams, dietary supplements [14].

Straw is the residue of the stalks after harvesting seeds, which was previously considered waste, but is now actively processed into useful raw materials. Areas of application include construction, namely the production of thermal insulation materials; eco-plates – mixtures of straw with lime, clay or cement. It is also used in the paper industry for the production of environmentally friendly paper, packaging, cardboard obtained from fiber, which reduces the need for felling trees, as well as in the production of biocomposites for automotive parts. Although oil flax produces shorter and lower-quality fiber than long flax, it is quite suitable for technical purposes. The advantages of using oil flax fiber in industry are that, unlike synthetic materials, flax products are completely recycled without harming the environment. The production of flax products consumes less energy than analogues made of wood or polymers. In addition, increasing the area under cultivation helps absorb CO_2 from the atmosphere and does not require a large amount of fertilizers and pesticides when growing [15].

The generalized chain of processing of oilseed flax – from seeds to finished ecological products – is shown in Fig. 2.

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[13] Gorach O. Current state of production and prospects of the use of oily flax seed in the food industry. *Monographic series «European Science»: Intellectual and technological potential of the XXI century: Innovative technology, Computer science, cybernetics and automation, Architecture and construction, Chemistry and pharmaceuticals*, 2023, Book 23, Part 1. P. 41-59. https://doi.org/10.30890/2709-2313.2023-23-01

[14] Gorach O., Dzyundzya O., Rezvykh N. Innovative Technology for the production of gluten-free food products of a new generation. C*urrent Nutrition & Food Science*, 2024, Vol. 20(6). P. 734–744. https://dx.doi.org/10.2174/0115734013280307231123055025

[15] Karahan M., Ahrari M., Karahan N. Composite Materials Market Research and Export Potential Analysis: A Regio-Global Case Study. *Recent Journal*, 2023 Vol. 70. P. 113–121. https://doi.org/10.31926/RECENT.2023.70.113

Enterprises using flax processing technologies in Ukraine are listed in Table 6.

Table 6

Flax product manufacturers in Ukraine

Enterprise	Products
LLC «Polish Flax Mill» Zhytomyr region	produces flax fiber and firewood for building materials
LLC «Konotop Flax Mill» Sumy region	specializes in flax processing and production of technical fiber
LLC «Korosten Flax Mill» Zhytomyr region	produces flax fiber for the textile and construction industries

Today, the requirements of European manufacturers of technical products made from short flax fiber require a minimum content of flaxseed in the fiber. Leading European manufacturers of industrial equipment use modern technologies for the production of nonwoven materials from flaxseed fiber: air-laying, carding, etc.

The technology for the production of nonwoven materials (insulation materials) by the air-laying method «AIRLAY LAROCHE» (France) involves the purification of short flax fiber to a flax content of no more than 7-8%. The cost of such fiber on the European market is 560-600 euros per ton [16].

The spikiness of flax fiber suitable for the production of nonwoven materials (insulation) by carding on the equipment of this company should not exceed 2-3%. The price of such fiber that meets the specified requirements on the European market is from 750 euros per ton.

[16] Karabay G., Sarıçoban K. Research on Competitiveness in Technical Textiles: Comparison of Countries Having the Lion's Share of Technical Textile World Exports and Turkey. *Fibres and Textiles in Eastern Europe*, 2021, Vol. 29(6(150)). P. 22-31. https://doi.org/10.5604/01.3001.0015.2718

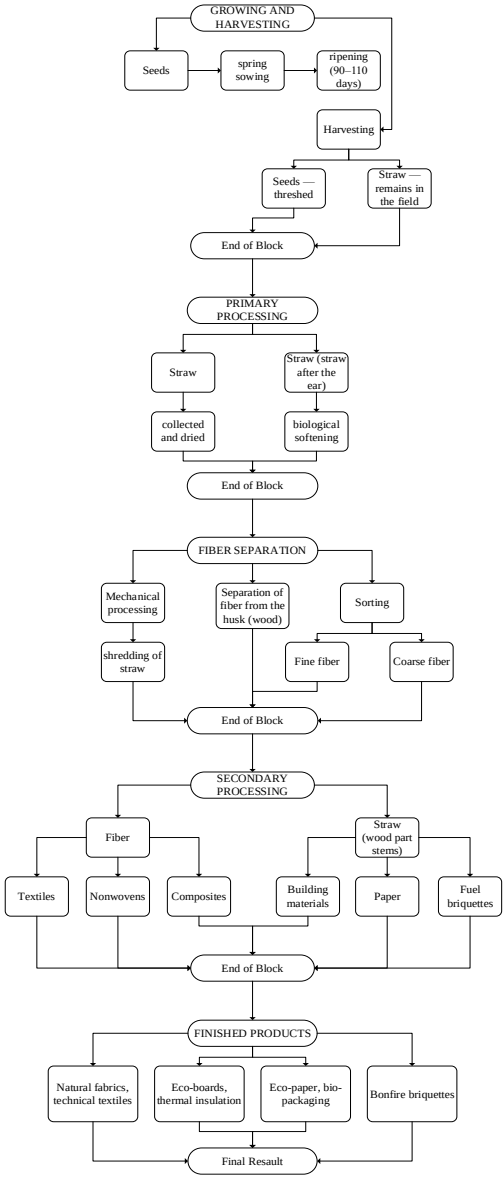

Fig. 2. Generalized chain of processing of oil flax

If the fiber is prepared using existing technologies on the «LAROCHE» line for the purpose of producing paper pulp, then it should have a spikiness within 1-25%. The cost of such fiber with a spikiness of 25% on the European market is 300 euros per ton. Thus, the lower the spikiness, the higher the quality of the fiber and, accordingly, its cost. For comparison, the price of coniferous bleached cellulose for the production of paper pulp on the European market is 800 euros per ton. The use of modern advanced technologies will allow the production of technical textiles for various functional purposes based on flax fiber, that is, to use the entire potential inherent in the plant, which will contribute to increasing the profitability of flax growing. Flax fiber can be used in the pulp and paper industry for the production of special durable banknote, cigarette and other types of paper. Due to its heat and sound insulation properties, the fiber and husk of this crop are suitable for use in the construction industry. Flax can also be used in the automotive industry for the production of insulation, parts, panels, in the production of geotextiles and composite materials, in agriculture, etc. Recently, there has been a tendency to increase the capacity of technical goods on the Ukrainian market. According to the results of literary studies, the volume of consumption of technical textiles has increased by 40% since the mid-1990s, and nonwovens by 67%. However, this growth is not provided by a significant increase in domestic production, but by imports. A characteristic feature of the Ukrainian technical textile market today is the very large advantage of imported goods over similar domestically produced goods. Currently, the volume of imports of nonwovens exceeds the volume of national production by 3.7 times. Unfortunately, the growth rate of domestic production of nonwovens in our country is significantly lower than the growth rate of imports [17].

It should also be noted that over the past 18 years, the domestic light industry has been in a state of protracted systemic crisis: business ties with traditional suppliers of raw materials have been destroyed, the production of equipment for light industry has practically ceased. In Ukraine, there are no state-owned enterprises for the production of nonwovens, there are only a small number of private enterprises. These are mainly joint-stock companies of a closed, open or public type and collective organizations.

Today, in Ukraine, the classification of technical textiles is carried out in accordance with the Ukrainian Classification of Goods for Foreign Economic Activity (UKT FEA) in accordance with the Law «On the Customs Tariff of Ukraine» dated 19.09.2013. No. 584-VII (as amended on 01.01.2017 in

[17] Hassan N., Sadek M., Shamandy E. The use of glass technology and technical textiles in the production of printed textile hangings to increase the awareness of the aesthetic side in medical institutions. *Journal of Architecture and Arts*, 2020, Vol. 5(19). P. 64-83. https://doi.org/10.21608/mjaf.2019.13553.1198

accordance with the amendments made by the Laws of 24.12.2015 No. 909-VIII, 04.10.2016 No. 1645-VIII, 20.12.2016 No. 1791-VIII) technical textiles belong to Section XI, Group 59 – textile materials, impregnated, coated or laminated; textile products for technical purposes.

In Ukraine, today, practically none of the government programs for the support and development of the textile and light industry, as well as the production of raw materials for it, are working. There is no general industry information and analytical center for light industry, no one carries out detailed statistical accounting of the volumes of output and other economic indicators of the work of enterprises. Classification, as a method of commodity science, will allow to systematize the entire variety of modern goods on the world market. The presence of a clear classification of goods according to certain characteristics will allow to limit access to the domestic market of potentially dangerous products.

Based on the results of the analysis, an expert survey conducted at enterprises for the production of technical fabrics and among specialists engaged in the production of technical textiles, it can be concluded that technical and special fabrics can be divided according to the following characteristics [18]:

1. Field of application: textiles for agriculture; construction textiles; textiles for footwear and ammunition; geotextiles (textiles for earthworks); home textiles; industrial textiles; medical textiles; textiles for mechanical engineering; textiles for environmental protection; packaging textiles; sports textiles and textiles for tourism and recreation.

2. Types of raw materials: natural fibers, artificial fibers, glass fibers; metal fibers; basalt and carbon fibers; other fibers.

3. Production technology: woven materials, woven, knitted, knitted products; nonwoven materials (filtering, insulation, fillers, absorbers, bases for other industries and other materials); coated textiles; textiles with additives. The classification of technical textiles is shown in Fig. 3.

Based on the analysis of works in the field of classification of technical textiles, it can be concluded that the importance of technical textiles is difficult to overestimate, since its areas of application are practically limitless. Today, there is a huge difference in the approach to the classification of technical textiles, therefore, for the further development of the production of technical textiles, a more in-depth study of the properties of materials and the unification of work on assessing the quality of products in this subsector, a clear classification is extremely important.

[18] Чурсіна Л.А., Горач О.О. Класифікація технічного текстилю – шлях до якості та безпеки. *Науковий вісник Полтавського університету економіки і торгівлі. Серія: Технічні науки*, 2020, № 1 (96). С. 113-120. https://doi.org/10.37734/2518-7171-2020-1-14

Despite the wide spread of technical textiles, there is no consensus in the textile industry on the creation and organization of a classification for technical textiles. It has also been established that there is no international system for the classification of technical textiles, as a result of which there is a certain technological and marketing barrier to industrial production and use of technical textiles in various industries, which is a significant obstacle to investing in this subsector of the industry at all levels of production and consumption of finished products.

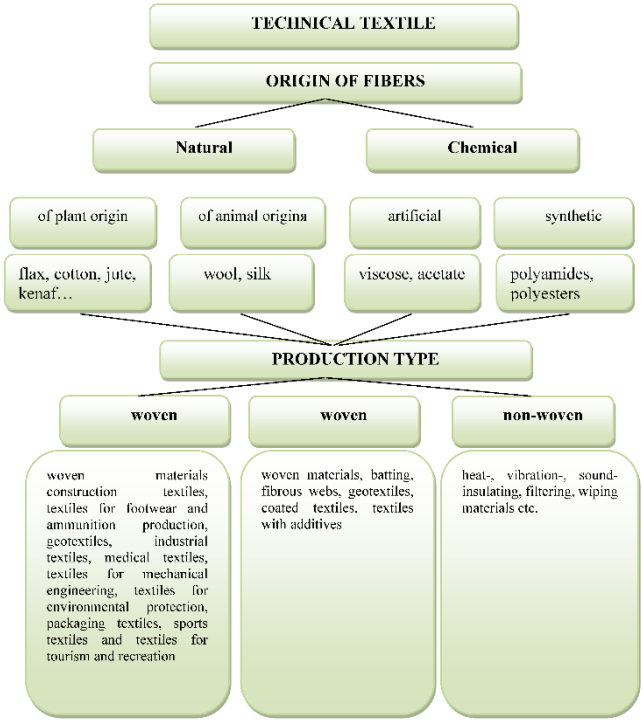

Fig. 3. Classification of technical textiles

Therefore, to ensure high quality of textile materials for technical purposes, it is necessary to invest and restructure the textile industry, develop processing production, and conduct scientific research to improve the effectiveness of protective equipment to provide special properties to textile materials depending on their purpose and operating conditions.

Analysis of the world production of technical textiles allows us to conclude that further development of the market for these products, according to experts, will be associated with the production of protective textiles, geosynthetics, "smart fabrics", medical materials and products, as well as environmentally friendly technical textiles for various functional purposes. The economic growth of the Western European textile industry is due to its transition from the production of clothing fabrics to the production of industrial fabrics using natural raw materials. In recent years, technical textiles have become the most high-tech product of the modern world economy, thanks to their inherent complex of physical, chemical, and functional properties [19].

Thus, taking into account the above and analyzing the areas of application of technical textiles and its classification in different countries of the world, we can conclude that an important task of this dissertation is to establish the physical and mechanical characteristics of flax oil fibers, which would become the basis for determining the criteria for their suitability for the production of high-quality technical materials and products for a specific purpose.

The use of flax oil fibers will allow farms that grow this crop to successfully sell straw at commercial prices, as is currently the case in European countries. The use of all the potential inherent in the plant – seeds, fibers and cobs – will improve the ecological situation in Ukraine, reduce the fire hazard situation in the south of Ukraine, where flax oil crops are mainly concentrated, and fill the domestic market with environmentally friendly products that will also find their consumer abroad.

The use of flax bast and oilseed fiber for the manufacture of technical products with the introduction of innovative technologies will allow domestic manufacturers to compete with foreign companies in the technical textile segment, which is the fastest growing in the world textile market. However, in order for the resulting products to compete with imported products, it is necessary to carry out scientific research and introduce into production innovative technologies for the use of flax oilseed fiber for the manufacture of technical products.

Currently, due to the increase in prices for cotton and wool raw materials, as well as taking into account the shortage of natural fibrous materials for textile enterprises in Ukraine, the question of replacing imported cotton with domestic raw materials has become acute. One of the sources of raw materials is flax oilseed, which until recently was considered a poorly suitable or even

[19] Bennato F., Ianni A., Innosa D., Grotta L., D'onofrio A., Martino G. Chemical-nutritional characteristics and aromatic profile of milk and related dairy products obtained from goats fed with extruded linseed. *Asian-Australasian Journal of Animal Sciences*, 2020, Vol. 33(1), P. 148-156. https://doi.org/10.5713/ajas.18.0868

unsuitable raw material, because the stems of this crop contain mostly short fibers.

Until a certain time, oil flax fiber was not used effectively enough, and even then only for the production of packaging materials, ropes, ropes, twine. However, provided that modern progressive technologies for the production of technical products are used, which are currently used in the EU countries, the fiber of this crop can be used for the production of technical textiles: nonwovens, insulation, geotextiles and agrotextiles. Therefore, oil flax fiber is a worthy alternative to cotton, which is imported into our country on the orders of domestic textile manufacturers. The use of our own cheap annually renewable raw materials in the domestic textile industry will help solve the problem of import substitution and will allow filling the Ukrainian market with environmentally friendly and safe technical products.

Cellulose-containing fiber of oil flax is much superior to cotton in its medical-biological and physical-mechanical properties. Due to such a unique complex of properties of flax as hygiene, high strength, low electrical resistance and ability to absorb dust, comfort, natural bactericidal properties (antiseptic and anti-rot), the demand for flax and flax-containing textile materials around the world is growing from year to year. Being an alternative to cotton fiber, flax can replace it in the production of products of leading sectors of the economy by 30-40% and thereby increase the country's financial independence from imports of cotton and finished products, including those of strategic purpose [20].

The introduction of innovative technologies for the production of technical textiles of various functional purposes using flax fiber is an important task of today, which will ensure the expansion of its application in industry. Since flax is an environmentally friendly raw material, this will allow for import substitution of cotton in the production of cellulose, geotextiles, composite and non-woven materials, sanitary and hygienic products, etc [21].

The leading manufacturer of composite materials, including those reinforced with natural fibers, in Ukraine is the subsidiary enterprise «Plastmas» of the limited liability company «Plastmas Trading House – Pryluky» (hereinafter the leading manufacturer of these products in Ukraine is the enterprise of the State Enterprise «Plastmas» LLC «Plastmas Trading

[20] Danish M., Ahmad T., Ayoub M., Geremew B., Adeloju S. Conversion of flaxseed oil into biodiesel using KOH catalyst: Optimization and characterization dataset. *Data in Brief*, 2020, Vol. 29, Article #105225. https://doi.org/10.1016/j.dib.2020.105225

[21] Deng Y., Chen J., Huang J., Yang X., Zhang X., Yuan S., Liao W. Preparation and characterization of cellulose/flaxseed gum composite hydrogel and its hemostatic and wound healing functions evaluation. *Cellulose*, 2020, Vol. 27(7). P. 3971-3988. https://doi.org/10.1007/s10570-020-03055-3

House-Pryluky»). The enterprise was established in 2003 on the basis of the Pryluky Plastics Plant, founded in 1931.

Currently, the range of products manufactured by the enterprise includes over 90 items. The basis of the product range is:

– polyvinyl chloride plastic compounds, which are the starting material for the production of insulation of protective sheaths of wires and cables;

– phenolic molding compounds (phenolic plastics), which are the starting material for the production of reinforced and unreinforced technical products;

– parts made of general and special-purpose plastics;

– high-pressure polyethylene compositions;

– polyvinyl chloride blocks made of PP-45 plastic compound;

– polyethylene pipes, bakelite varnishes, etc.

The company's products are widely used in mechanical engineering, mining, oil and gas, electrical engineering, transport and other industries, the military-industrial complex, the production of sports and recreation goods and footwear. In addition, the SE «Plastmas» LLC «TD Plastmas-Pryluky» operates a workshop for processing secondary materials, which produces polyvinyl chloride, polyethylene, polypropylene, containers and packaging materials (cardboard and paper bags). Cotton fiber imported from Uzbekistan is used to reinforce phenolic plastics at the enterprise.

In our opinion, SE «Plastmas» LLC «TD Plastmas-Pryluky» can become a potential consumer of domestic raw materials – bast and oil flax fiber, using them in the production of fillers for composites and the manufacture of packaging materials.

It is known from the works of domestic and foreign scientists that flax fiber is widely used for the manufacture of composite materials. In some northern countries (Finland, Norway, Germany) flaxseed crops are oriented towards the industrial use of fiber for the production of composite materials. Scientists from different countries of the world, in particular, Langer E. (Germany), Kathleen VDV. (Belgium), Ton-That MT, Denault J. (Canada), Mieleniak V., Bagley S., d'Anselme T., Guyader J. (USA), Pallesen (Denmark), etc. have successfully conducted research on the modification of natural fibers to obtain polymer composite materials with natural fibers as fillers. However, the theoretical justification of this process and a detailed description of the technologies for manufacturing polymer composite materials reinforced with natural fibers are not given in their works.

Taking into account the above, the direction of research was chosen during the implementation of this dissertation work – the development of a technology for obtaining from flax straw stalks oil technical textiles with

certain physical and mechanical characteristics and physical and chemical indicators, suitable for reinforcing composite materials.

Successful production implementation at Ukrainian enterprises of the developed innovative technology for the production of technical textiles using annually renewable raw materials – oil flax fibers – will contribute to the entry of domestic competitive products into the world market.

CONCLUSIONS

The need and rationality of increasing the production of technical textiles in the world, as well as in Ukraine, is justified by considerable factors, in particular, the sustainable development of its potential raw material base – the sown areas allocated for oil flax. Recently, Western Europe and other countries of the world have shown increased interest in the use of oil flax for the manufacture of various types of technical products in many industries. Based on the world experience in the use of oil flax straw, it can be concluded that it is a valuable raw material for the manufacture of technical products, which are widely used in many industries. Although today in our country the straw of this crop remains a secondary product, with a certain processing technology it can be used for the manufacture of the above-mentioned consumer goods.

However, there is a certain technological and marketing barrier to the industrial use of oil flax straw – the lack of information on the development and testing of technologies for obtaining fiber with the necessary physical and mechanical indicators, suitable for the production of technical textiles for reinforcing composite materials. The integrated use of oil flax in industry will also allow solving the problems associated with the shortage of raw materials, which were previously obtained from technical crops: long flax, cotton, hemp, etc. However, the use of oil flax as a raw material for obtaining a wide range of technical textiles of various functional purposes is possible only if its physical and mechanical properties meet the requirements of the production technologies of specific groups and types of industrial materials. These properties of flax raw materials must be formed under certain modes and parameters of the technological process of its primary processing when using innovative technologies for the integrated processing of oil flax straw stalks.

SUMMARY

The modern economy requires continuous improvement of quality and expansion of the range of products. The use of environmentally friendly materials and the development of innovative technologies for obtaining technical textiles of various functional purposes is an urgent task. The areas of application of technical textiles are constantly expanding. They arise on

the basis of a combination of inventive activity and marketing methodology based on the study of consumer needs. The source of environmentally friendly raw materials for the production of technical textiles in Ukraine is fiber from bast crops. However, today there is almost no data on scientific research and production tests in the field of using bast fibers for the production of technical textiles. There is also almost no data on the physical and mechanical characteristics of fibers suitable for the production of technical textiles.

Based on the above, we can conclude that the issue of developing the scientific foundations of obtaining bast fiber fillers for the production of technical textiles is of particular relevance. Advanced processing of oil flax straw stalks to obtain bast, and subsequently fiber, with the necessary physical and mechanical characteristics for the production of environmentally friendly organic technical textiles for various functional purposes is an important task of the flax processing industry.

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