MODERN PLANT PRODUCTION TECHNOLOGIES IN THE FACE OF CLIMATE CHANGE

SCIENTIFIC EDITORS: PIOTR PONICHTERA, JOLANTA PUCZEL

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Chapter 2.

SCIENTIFIC FOUNDATIONS OF COMPLEX PROCESSING AND USE OF STALKS AND SEEDS OF FLAX OIL

Olha Horach

2.1. Introduction

This monograph is devoted to highlighting the modern achievements of scientists in Ukraine and abroad on the issue of the comprehensive use of oil flax in the field of studying the anatomical, morphological and technological properties of seeds, straw and fiber of oil flax, processing seeds into biologically active substances and food products, developing innovative technologies for obtaining flax fiber and using it for the production of technical textiles. Oil flax crops in Ukraine and in the world are growing significantly. The increase in the area sown under this crop is explained by the fact that oil flax seeds have found wide use in the pharmaceutical industry abroad and in Ukraine to produce biologically active additives. Flaxseed oil contains 16-24% protein, many amino acids, alpha-linolenic acid Omega-3 and Omega-6, which are of great importance in the treatment of cancer, mineral supplements, trace elements and vitamins, as well as phytoreagents that have antioxidant and medicinal properties.

Flaxseed is currently very popular as a food supplement. Bakery products with the addition of flaxseed acquire a delicate taste, due to the large amount of fat, and an attractive crust. Studies have shown that the consumption of bread enriched with flaxseeds reduces cholesterol by 7-9% within four weeks. The possibility of using flaxseed flour for the preparation of gluten-free confectionery has also been proven. Analyzing the world experience in the use of flaxseed and oil, we can conclude that the scope of their application is expanding every year and has a rapid growth trend. This is explained by the unconditional value of the seeds, namely the presence of nutrients.

Production and scientific research indicate the prospects and economic feasibility of expanding the area of oil flax shown. But, unfortunately, the stems of this crop are practically not used. Oil flax straw is most often burned in the field. It is believed that it contains a small amount of fiber and its extraction is unprofitable. Therefore, at present, technologies for primary processing straw into bast, technologies for obtaining trusts and fiber have not been developed. But, as world experience in using oil flax straw shows, it is a valuable raw material for obtaining various types of products for many industries. Therefore, in modern conditions, the problem of developing new resource– and energy-saving technologies for processing oil flax straw stems has arisen, the use of which will solve the problems associated with the shortage of raw materials and energy reserves and will contribute to reducing the costs of producing various products.

The monograph is devoted to the issue of the integrated use of oil flax. To achieve the set goal, the following tasks were solved in the work: to study the domestic and world market for the production of oil flax, to give a general and agro-technological characteristic of oil flax, to analyze the world and domestic experience in the use of oil flax, to study the use of oil flax fiber for the production of technical textiles, to consider the problems and prospects of the production of technical textiles in Ukraine, to analyze the use of oil flax seeds in the food industry and to determine the methods of producing oil from oil flax seeds.

The scientific novelty of the monograph lies in the fact that, based on theoretical data and experimental studies, the feasibility of the integrated use of oil flax in industry has been substantiated. The possibility of using oil flax fiber in the production of technical textiles, oil flax seeds in food preparation technologies for enriching the nutritional composition of recipes and as biologically active additives has been scientifically substantiated.

Considering the above, the issue of the integrated use of flax oil is of particular relevance, since its implementation will contribute to increasing the profitability of growing flax oil and solving the problem of the crisis state of the domestic energy sector and providing raw materials for many industries. The integrated use of flax oil in industry will also allow solving problems associated with the shortage of raw materials obtained from industrial crops: long flax, cotton, hemp, etc. However, the use of flax oil as a raw material for obtaining cellulose-containing materials is possible provided that its physical and mechanical properties meet the requirements of the technology to produce industrial materials. These properties of flax raw materials must be formed under certain growing conditions and at certain stages of the technological process of its primary processing when using world innovative technologies for its integrated processing.

2.2. General and agro-technological characteristics of oil flax

Oil flax is a valuable technical crop with many uses (Fig. 1). Its botanical name Linum usitatissimum means «the most useful. Oil flax seeds (Fig. 2) contain 40-50% fat, which dries quickly (iodine value – 175-195), forming a thin, smooth, shiny film. The high-quality oil obtained from it is widely used in many industries: in the paint and varnish industry to produce natural drying oil, varnishes, enamels, various paints for underwater work; electrical, aviation, automotive, shipbuilding, foundry, metalworking, medical, perfumery and cosmetic, etc. Linseed oil is indispensable in the production of lithographic paints, linoleum, oilcloth, waterproof fabrics. Sometimes fresh flaxseed oil in its natural form is used as a food product.

Flax is an important medicinal plant. Flaxseed oil is used in the diet of patients with impaired fat metabolism, diabetes, atherosclerosis, ischemic heart disease, brain disease, hypertension, etc.[1.]

Oilseed production waste – cake and oilcake – is a valuable concentrated feed containing up to 1.2 feed units, 31-38% digestible protein and about 9% fat. In terms of feed qualities, it surpasses other plants, because it is easily digested by animals.

Fig. 1. Flax seed

Source: Internet resource Liktravy. Access mode https://liktravy.ua/herbs/lonu-nasinnja

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

Fig. 2. Boxes with flax seeds

Source: Proposal – The main magazine on agribusiness. Access mode – https://propozitsiya.com/ua/lon-oliynyy-osoblyvosti-vyroshchuvannya

As a result of research by several scientists of the last century, it was proven that the yield of fiber from oil flax is from 10.5 to 16.6% of the mass of all straw. If we assume that the average fiber yield is 12%, and the straw yield is 8.5 $c \cdot ha^{-1}$, then from one hectare of flax after processing you can get about a hundredweight of fiber. Straw, which contains up to 50% cellulose, is a raw material to produce cigarette paper and cardboard. From the waste of flax fiber production – flaxseed – by pressing, you can make boards that are used as a building material. In addition, flaxseed briquettes are high-quality fuel[2].

Flax has been part of human life since ancient times: in India, China, Egypt, and Transcaucasia it was used 3-4 thousand years BC. In fragments of fused buildings in Switzerland, dating back to the Stone Age, flax stalks

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

with boxes and seeds, remains of flax fabrics, threads, ropes were found. 5 thousand years BC in Egypt flax was a well-known crop – mummies were wrapped in linen cloth. Ancient Slavic tribes also knew this crop well and knew how to make yarn from flax fiber, and oil from seeds. Flax began to be sown in the territory of modern Ukraine in the 6th century AD. During the time of Kievan Rus, all tribes were engaged in flax growing, according to chroniclers. In the 12th-16th centuries, flax became the main technical crop of all Russian principalities, was widely used in trade with overseas countries, and a state duty was imposed on it. According to FAO, the area shown for oil flax worldwide is almost 3.5 million hectares.

Flax is cultivated in many countries of the world (Fig. 3). More than 70% of the flax sown areas in the world are occupied by oil flax. Recently, Canada and the USA have been developing oil flax production very intensively[3]. Information on the areas shown under oilseed flax is presented in Table 1.

Fig. 3. Flax-growing countries (shaded)

Source: Scientific development of innovative technologies of obtaining composite materials from oilseed flax fibers. Access mode – http://vat.ft.tul.cz/2021/4/VaT_2021_4_4.pdf.

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

Table 1. Flaxseed sowing areas in the world

Country name	Area, thousand hectares	Country name	Area, thousand hectares
Worldwide	3489,786	Mexico	0,002
Europewide	598,111	Nepal	55,000
By country:		Netherlands	4,000
Austria	4,000	New Zealand	0,500
Argentina	101,000	Pakistan	7,974
Afghanistan	39,000	Poland	3,724
Bangui	68,820	Russian Federation	61,250*
Belarus	70,000	Romania	2,504
Belgium	10,000	Slovakia	0,322
Bulgaria	0,058	United Kingdom	101,000
Brazil	17,000	United States	135,170
Hungary	0,200	Tunisia	2,200
Germany	110,048	Turkey	0,300
Egypt	15,000	Uzbekistan	3,000
India	930,000	Ukraine	26,000
Iraq	0,590	Uruguay	2,500
Iran, Islamic Republic of	0,744	France	44,500
Spain	91,000	Croatia	0,015
Italy	1,000	Czech Republic	2,017
Kazakhstan	50,000	Chile	1,000
Canada	811,500	Sweden	14,100
Kenya	0,900	Ecuador	0,075
China	570,000	Eritrea	3,000
Latvia	2,200	Estonia	0,323
Lithuania	6,100	Ethiopia	71,000

Source: Scientific development of innovative technologies of obtaining composite materials from oilseed flax fibers. Access mode – http://vat.ft.tul.cz/2021/4/VaT_2021_4_4.pdf.

Analyzing the data given in Table 1, we can conclude that the leading producers of oil flax in the world are now Canada, China, India, Argentina, the USA and Russia. The total gross seed harvest in these countries is 1.2 million tons. World experience in using oil flax straw shows that it has a wide range of applications. In Ukraine, this crop was unjustifiably forgotten for many years due to the socio-political processes that have taken place in our country for centuries. Today, oil flax is returning to Ukraine[4]. A large range of varieties, their diversity, and high profitability contribute to the rapid spread and annual increase in the area shown under this crop.

Flax is one of the few promising niche crops, the economic potential of which for agribusiness remains almost unknown. In the world in agriculture, this crop has been known for a long time, but in recent years it has been almost forgotten by domestic agribusiness. Both long flax and oil flax are grown in our conditions. Long flax is a spinning crop, the stems of which form fibers with valuable technological properties, namely flexibility, fineness and high strength. Oil flax is a crop from which raw materials to produce industrial oil are obtained. Flax also has a special agrotechnical value as the best precursor for winter cereals. In addition to the above, flax seeds are in demand as a useful dietary supplement, and its cake has a high feed value compared to others.

First, this crop is in high demand among traders on the market due to the high oil content of the seeds, which on average for different varieties ranges from 44% to 50%, and among farmers – due to the yield of up to 2.0-2.5 $t{\cdot}ha^{-1}$ and higher with low production costs during cultivation and minimal use of pesticides. Purchase prices for flax are less dependent on seasonal fluctuations and market conditions, unlike sunflower or soybean. The same applies to export prices, which are almost an order of magnitude higher than traditional grain and oilseed crops[5]. Table 2 shows the import and export of flax seeds by Ukrainian enterprises according to the analysis of customs statistics.

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4 Anusudha, V., Sunitha, V., Mathew, S. (2020). Performance of coir geotextile reinforced subgrade for low volume roads. Int J Pavement Res Technol. https://doi.org/10.1007/s42947-020-0325-4

5 Gorach, O. (2023). Current state of production and prospects of the use of oily flax seed in the food industry. Intellectual and technological potential of the XXI century: Innovative technology, Computer science, cybernetics and automation, Architecture and construction, Chemistry and pharmaceuticals. Monographic series «European Science». Book 23. Part 1, 41-59. https://doi.org/10.30890/2709-2313.2023-23-01-014

Table 2. Import and export of flax seeds by Ukrainian enterprises

Years	Import volume, tons	Cost, $ thousand	Average import price of 1 ton, $	Export volume, tons	Cost, $ thousand.	Average export price of 1 ton, $
2011	137	110	802,92	10694	18640	1743,03
2012	184	162	880,43	22684	44956	1981,84
2013	84	45	535,71	7087	10935	1542,97
2014	75	83	1106,67	10221	22106	2162,80
2015	127	142	1118,11	12389	29462	2378,08
2016	133	134	1007,52	15300	44089	2881,63
2017	134	72	537,31	19394	56919	2934,88
2018	569	1522	2674,87	5878	12909	2196,16
2019	227	486	2140,97	5887	11269	1914,22

Source: Current state of production and prospects of the use of oily flax seed in the food industry. Access mode – DOI: 10.30890/2709-2313.2023-23-01

Analyzing the data in Table 2, we can conclude that today there is a significant demand in the global agricultural market for domestic flax seeds, which are purchased in many countries of the world at an attractive price. In 2016-2017, the average annual export price of 1 ton of flax seeds reached almost $ 3,000, while for rapeseed, for example, it did not exceed $ 394.8-412.7. The advantages of growing oil flax include firstly, that oil flax is not demanding on natural conditions. Flax is cold-resistant, so it is sown immediately after spring barley. Flax seeds begin to germinate at a soil temperature of 3-5°C, and at 7-8°C it can sprout in 5-7 days. Shoots withstand short-term frosts down to -3-4°C. Secondly, oil flax loves moisture, but tolerates drought well. The advantage of flax is its drought resistance due to the peculiarities of its root system. This is due to arid climatic conditions. Thirdly, it does not break. The growing season lasts 84-86 days. Seed moisture is not a problem. Although the harvest begins in August, it can stand until mid-late September. At the same time, it does not crumble. Fourthly, there is a small amount of seed material. The standard flax sowing rate is 4.5-5 million seeds·ha^{-1}, 30-35 kg·ha^{-1}. However, some practicing farmers stated that the rates could be reduced.

The disadvantages of flax cultivation include firstly, oil flax has high requirements for soil fertility. Flax has a higher yield on black soil, and it is not recommended to sow flax on heavily waterlogged and saline soils. In addition, it is recommended to plant crops mainly on soil with sufficient nutrient content. Secondly, oil flax is a crop with a small leaf area and cannot compete with weeds. Therefore, special attention should be paid to prevention and control before and after sowing. Thirdly, plant protection methods. Crops are sprayed to protect against pests such as fusarium, anthracnose, rust and flax flea. Affected flax crops are sprayed with herbicides from a tank mix. Fourth, flax needs fertilizer. Sulfur is added to the soil before planting. Phosphorus and potassium fertilizers are applied during the main plowing, and nitrogen fertilizers in the spring. Flax requires compliance with agricultural cultivation techniques. In addition, they will differ for different agroclimatic conditions[6].

Based on the advantages and disadvantages of growing oilseed flax, we can conclude that flax is a profitable crop, the cultivation of which is cheaper than traditional oilseed crops. However, it is necessary to develop your own cultivation strategy, which will allow you to get high yields. The issue of selling seed material remains unresolved. On the one hand, the price of flax is higher, but at the same time it is mainly an export crop. Therefore, traditionally, logistics costs and risks will fall on the farmers' wallets and reduce profitability.

The dynamics of the sown areas allocated for oilseed flax in Ukraine are shown in Fig. 4, Table. 3.

[6] Amna Pervaiz, Farooq Azam, Ahsan Ahmad. (2024). Investigation of Static and Dynamic Mechanical Properties of Eco-Friendly Textile PLA Composites Reinforced by Flax Woven Fabrics International Journal of Polymer Science. https://doi.org/10.1155/ijps/2821777

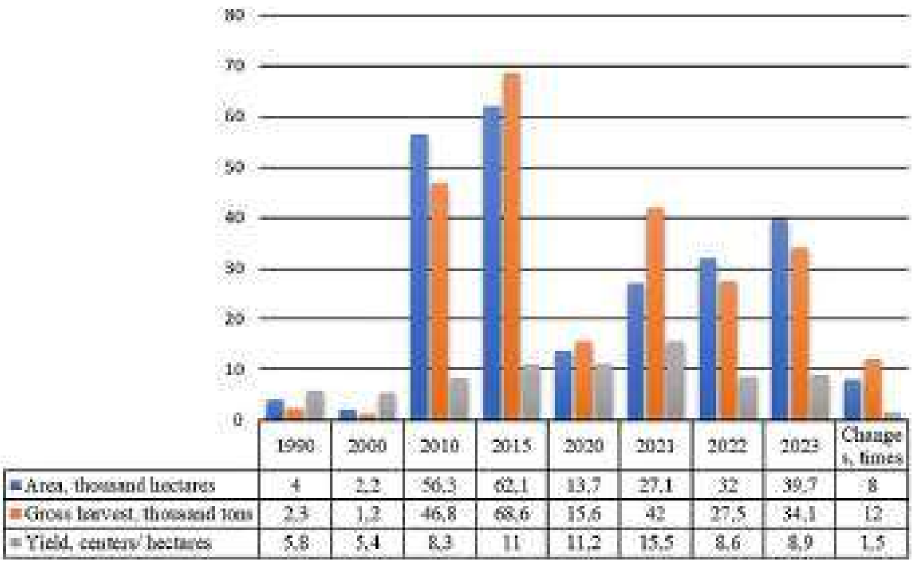

Fig. 4. Dynamics of sown areas allocated for oilseed flax in Ukraine

Source: according to the State Statistics Service of Ukraine. Access mode – https://www.ukrstat.gov.ua/

Table 3. Production of oil flax in Ukraine

Year	Area, thousand hectares	Gross harvest, thousand tons	Yield, centers/ hectares
1990	4,0	2,3	5,8
2000	2,2	1,2	5,4
2010	56,3	46,8	8,3
2015	62,1	68,6	11,0
2020	13,7	15,6	11,2
2021	27,1	42,0	15,5
2022	32,0	27,5	8,6
2023	39,7	34,1	8,9
Changes, times	8	12	1,5

Source: according to the State Statistics Service of Ukraine. Access mode – https://www.ukrstat.gov.ua/

The above diagram shows that there is a tendency to a rapid increase in the area sown under oil flax, but, unfortunately, this valuable crop is not fully used by industry. This is primarily due to the lack of technology for preparing straw from oil flax, which would allow obtaining fiber with new technological characteristics, suitable for use in many industries.

In recent years, in the south of Ukraine, such an unconventional crop as oil flax has been introduced into crop rotations. This is due to the fact that oil flax seeds can be an alternative to the seeds of other oil crops.

Oil flax has proven itself to be a drought-resistant, early ripening crop, resistant to lodging and cracking of the pods. In addition, the crop has proven to be a good precursor for winter crops.

Breeders of the Institute of Oilseed Crops of the Ukrainian Academy of Sciences have created a pipeline of technical varieties with different growing periods, which are characterized by a high oil content of 47-50% and a potential yield of up to 25 $c \cdot ha^{-1}$.

The Register of Plant Varieties Suitable for Distribution in Ukraine contains 52 varieties of flax, including long flax – 23 varieties, common winter flax – 1 variety, common spring flax – 1 variety, curly flax – 27 varieties, as well as 11 varieties of flax of foreign selection, which makes up 21% of their total number. Below is a description of some modern varieties of oilseed flax[7].

The Iceberg variety has been in the Register of Plant Varieties of Ukraine since 2001; it was created at the Institute of Oilseeds of the Ukrainian Academy of Sciences by the method of induced mutagenesis by irradiating seeds of the Tsian variety with gamma rays. The height of the plants is 54-57 cm. The duration of the growing season is 86-88 days. The variety is distinguished by its drought resistance and resistance to lodging of plants. In field experiments of the Institute of Agriculture of the Southern Region of the Ukrainian Academy of Sciences (2004), its seed yield was 20.8-21.8 $c \cdot ha^{-1}$. It is recommended for cultivation in the steppe zone of Ukraine.

The Vera variety was created at the Askaniyske State Agricultural and Food Plantation. It is positioned as a food variety. Plant height is 48-52 cm. The duration of the growing season is 75-88 days. Drought-resistant,

[7] State Register of Plant Varieties Suitable for Distribution in Ukraine [Electronic resource]. Access mode: https://sops.gov.ua/ua/derzavnij-reestr

resistant to lodging of plants and disease. Average seed yield – 1.7-1.9 t·ha^{-1}. Potential yield – up to 25 c·ha^{-1}.

The VNIIMK variety was created by individual selection from a hybrid combination. Plant height – 61 cm, duration of the growing season – 88-92 days. Fiber productivity – 70-94 g·m^{-2}. Fiber content is about 15%. The degree of damage by fusarium is very low, high resistance to lodging.

The Zolotysty variety was created by induced mutagenesis. Plant height – 65 cm. Duration of the growing season – 88-90 days. It has characteristic distinguishing features – chlorophyll deficiency of the plant apex throughout the growing season, white corolla and yellow seeds. Drought-resistant, resistant to lodging of plants and disease damage. Since 2005, the Zolotysty variety has been included in the State Register of Plant Varieties Suitable for Distribution in Ukraine.

The variety Debut has been in the Register of Plant Varieties of Ukraine since 2001; created at the Institute of Oil Crops of the UAAS by the method of individual selection from a variety sample from the collection of the Institute of Oil Crops of the UAAS. Plant height is 57-58 cm. The duration of the growing season is 85-87 days. The bush is compact, the stem is weakly branched. The variety is distinguished by its resistance to lodging of plants and shedding of seeds. It is characterized by high potential productivity. In field experiments of the Institute of Agriculture of the Southern Region of the Ukrainian Academy of Sciences since 2004, the seed yield is 23.7-27.2 c·ha^{-1}. Recommended for cultivation in the steppe zone of Ukraine.

The Kivik variety has been included in the Register of Plant Varieties of Ukraine since 2007. It was created by the method of individual selection from a mutant line obtained by induced mutagenesis. The Kivik variety is distinguished by the changed chemical composition of the oil in the seeds, namely, a low content of linolenic acid and the presence of up to 40% oleic acid. Therefore, it is positioned as a food variety. Resistant to drought and diseases. It has a bright purple color of flowers. Plant height is 50-60 cm. The duration of the growing season is 75-83 days. The average seed yield is 1.7-1.9 t·ha^{-1}. The potential yield is 25.3 c·ha^{-1}.

The variety Pivdenna nich has been in the Register of Plant Varieties of Ukraine since 2001; it was created at the Institute of Oilseeds of the Ukrainian Academy of Sciences by the method of microgametophytic selection from a hybrid combination. The height of the plants is 52-55 cm. The duration of the growing season is 84-86 days. The variety is distinguished by its resistance to drought and lodging of plants. It is characterized by high potential productivity. In the demonstration experiment of the DPDG "Askaniyske" (2004), the seed yield was 18.0 $c \cdot ha^{-1}$, and in field experiments of the Institute of Agriculture of the Southern Region of the Ukrainian Academy of Sciences (2004) – 22.0-24.3 $c \cdot ha^{-1}$.

The Orpheus variety has been in the Register of Plant Varieties of Ukraine since 2002; it was created at the Institute of Oilseed Crops of the Ukrainian Academy of Sciences by individual selection from a hybrid composition. Plant height is 55-60 cm. The duration of the growing season is 86-88 days. The variety is distinguished by high resistance to shedding, resistant to lodging of plants. It is characterized by high potential productivity. Yield is 22.7 $c \cdot ha^{-1}$.

The Rucheek variety is a mid-ripening variety of oil flax. Highly productive, with a high oil content in seeds. The period from full germination to technical ripeness of seeds is 80-85 days. Resistant to fusarium. The optimal plant density is 500-600 $pcs \cdot m^{-2}$. Well adapted to various soil and climatic conditions. Potential seed yield and maximum yield in production are up to 25 $c \cdot ha^{-1}$.

Lights of Dniprohesu (2018). Mid-ripening. The duration of the growing season is 88 days. The marker trait is chlorophyll deficiency of the plant from the beginning of the growing season to ripening. The height of the plants is 50-51 cm. The weight of 1000 seeds is 7.7 g. The oil content in the seeds is 48-49%. The linolenic acid content in the oil is 70%. The potential yield is 2.0 $t \cdot ha^{-1}$. The variety is technological, does not lodge, does not crumble. Recommended for cultivation in all soil and climatic zones of Ukraine.

Zhivinka (2018). Mid-ripening, drought-resistant. The duration of the growing season reaches 88 days. The flower is medium-sized, the color of the corolla petals is blue, the anthers are blue, the seeds are moderately brown. The height of the plants is 50-52 cm. The weight of 1000 seeds is 5.5-6.2 g. The oil content in the seeds is 47%. It has a potential yield of about 1.8-2.0 $t \cdot ha^{-1}$. The food variety is characterized by a reduced content of linolenic acid in the oil (25.9%) and an increased content of oleic (20.6%) and linoleic (43.6%) acids. The variety is technological, does not settle, does not crumble, is suitable for mechanized cultivation.

Zaporizhia Bogatyr (2018). Mid-ripening. The duration of the growing season is 90–91 days. The height of the plants is 52 cm. Large-seeded, weight of 1000 seeds – 9.8 g. The oil content in the seeds is 49.5%.

The linolenic acid content in the oil is 65%. The potential yield is about 2.1-2.5 t·ha^{-1}. The variety is technological, does not lodge, does not crumble. Recommended for cultivation in all soil and climatic zones of Ukraine.

Patritsii (2018). Mid-ripening, drought-resistant. The duration of the growing season is 86-87 days. Marker features are a semi-collapsed degree of flower opening, purple corolla petals and yellow seed color. Plant height is 50-55 cm. The weight of 1000 seeds is 7.0-7.2 g. The oil content in the seeds reaches 48%. The potential yield can be 2.0-2.5 t·ha^{-1}. Technical variety, linolenic acid content in oil – 68.4%. Technological variety, does not lodge, does not crumble, suitable for mechanized cultivation.

Dobrodar (2022) Variety characteristics: seed yield – 2.5 t·ha^{-1}, weight of 1000 seeds – 8.4 g, oil content in seeds – 48.1%, linolenic acid content in oil – 55.25%, linoleic acid – 11.51%, oleic acid – 23.24%. The duration of the growing season is 80-85 days, plant height – 58-69 cm. It is distinguished by high (9 points) resistance to lodging, drought, and shedding. Due to wild plasma, it has high (7-8 points) resistance to pathogens (fusarium wilt, rust, streak, anthracnose) and damage by pests (flax flea, flax thrips, flax fruit fly). Does not contain GMO structures. Recommended for cultivation in the Forest-Steppe and Steppe zones.

Linsan (2022). Variety characteristics: seed yield – 2.0 t·ha^{-1}, weight of 1000 seeds – 5.1 g, oil content in seeds – 42.3%, changed ratio of unsaturated fatty acids in oil (reduced content of linolenic acid – 3.01%, increased content of linoleic – 72.32%, oleic – 16.90%). The duration of the growing season is 85-87 days, plant height – 55-68 cm. It has high (9 points) resistance to lodging, drought, and shedding. It is distinguished by a combination of distinctive (marker) morphological features – white color of corolla petals and spotted yellow-brown seeds. Does not contain GMO structures. It is recommended for cultivation in the Forest-Steppe and Steppe zones.

According to analysts' forecasts, the area of oilseed crops will be expanded due to their greater profitability compared to cereals, oilseed flax is no exception, remaining a niche crop.

The sown area may be the largest in the last 6 years. Current weather conditions give reason to expect a yield above the average for the last three years. The flax harvest is expected to be 40-41 thousand tons[8].

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[8] Varietal resources of oilseed flax [Electronic resource]. Access mode: https://propozitsiya.com/ua/sortovi-resursi-lonu-oliynogo

The reason for the increase in the sown area is that flax does not require large capital investments, since its cultivation is 1.1-1.3 times cheaper than sunflower production. At a price of 12 thousand $t·ha^{-1}$ and a yield of 0.7-0.8 $t·ha^{-1}$, its profitability is positive.

Unfortunately, the market for counterfeit seeds in Ukraine is large: many producers grow flax varieties of unknown origin and with questionable seed quality. This affects the crop yield and the final price of the grown product[9].

Experts from the Research Institute of Oilseeds noted that high-quality and certified seeds produced as commercial flax are sold at lower prices, as a result of which farmers lose the yield of this crop. According to industry experts, one of the main tasks in growing flax is the varietal purity of seed material. Experts carry out two types of cleaning of flax crops: the first – during the flowering period, when the color of the flowers of the main varieties disappears, it is possible to distinguish impurities from other varieties, the second – at the early yellow stage of ripening, taking into account the height of the plant, the shape of the bush and the yield obtained. In accordance with current instructions, crop varieties are tested at the stage of full flowering of the plant.

Varietal renewal on the farm's seed plot occurs once every three years with seeds of the first reproduction of the entire area. The seeds must be free from weeds, sorted, disease-free, not less than the third time of reproduction, high-quality, with high germination up to 1000 seeds. Using most of the seeds for sowing helps to increase germination rates in the field. It is forbidden to sow seeds affected by the weevil. Seeds of quarantine weeds and live pests and their larvae are not allowed in the sowing materials.

One of the main reasons why it is worth taking care of growing flax for oil is the economic component. Due to the high oil content of 45-50% and the potential yield of 2.0-2.5 $t·ha^{-1}$, oil flax is a highly profitable crop and very attractive to agricultural producers.

Growing oil flax does not require large material costs, since the cost of growing it is on average 1.1-1.3 times cheaper than production sunflower. The cost price per hectare is 8-10 thousand UAH, and the profit per hectare

9 Horach, O.O., Dombrovska, O.P., Chursina, L.A. (2021). Innovative directions of using oilseed flax and ecological safety of food products. Collective monograph "Formation of a new paradigm of the development of the agro-industrial sector in the 21st century". Vol. 2. Kherson, 593-619. doi:10.30890/2709-2313.2023-23-01

reaches 8.0-11.5 thousand UAH per ton and the yield is 0.7-0.8 centners/hectare, so the profitability is positive[10].

A prerequisite for the development of resource-saving technologies for processing oil flax straw is a more in-depth study of the anatomical, morphological structure and chemical composition of oil flax and long flax stems. Knowing the morphological structure of the stems, it is possible to predict the fiber yield and its quality characteristics, and accordingly its functional purpose, within certain limits.

The stem is the productive part of flax. There are general and technical stem lengths. The first is measured by the distance from the place of attachment of the cotyledons to the top of the capsule, the highest located in the inflorescence, the second – from the place of attachment of the cotyledons to the beginning of the branching of the inflorescence.

The two groups of flax – oil flax and long flax – differ greatly from each other in the length and thickness of the stem.

It is known that fiber with higher quality indicators is obtained from thinner stems. Flax stems with a diameter of 1.1-1.3 mm are considered thin if their length exceeds 80-85 cm, and thick if their length is 50-55 cm. The stems of the studied varieties of oil flax with an average technical length of 44 cm have a diameter of 1.3 mm in the middle part, therefore they are thick. In long-stemmed flax, the length of the technical part of the stem is 60-90 cm, and the thickness is 0.8-1.2 mm, therefore it is classified as a thin-stemmed plant. The ratio between the length and thickness of the stems determines the value of such indicators as compactness and convergence.

The ratio of the thickness of the stem to its length is called convergence, and the ratio of the length of the stem to its thickness is called compactness. The results of studies by many scientists show that compactness and convergence characterize the content and quality of fiber in the stems. The anatomical structure of the stem largely depends on its external properties: total and technical length, thickness, branching, length of the branched part, color, degree of development of the root system, etc. The high content of wood in the stems affects the specific content of fiber in them, therefore, in stems with a wide cross-section, the fiber content is lower than in thin stems.

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10 Umair, M., Ullah, T., & Nawab, Y. (2023). 3D Natural Fiber Reinforced Composites in Natural Fibers to Composites. Engineering Materials. In book: Natural Fibers to Composites, 41-78. http://dx.doi.org/10.1007/978-3-031-20597-2_3

The external shape of the stem can determine the quality of the fiber contained in it. It is known that the bast bundles of long flax consist of longer cells than in oil flax. This determines their high specific strength. Long and thin elementary fibers provide a large surface of mutual contact, due to which the strength of the technical fiber increases. The strength of adhesions, in turn, depends on the chemical composition of adhesives, i.e. pectin and lignin. Lignin increases the strength of adhesions, and therefore of the technical fiber. Since the length of the elementary fibers in oil flax is shorter than in long flax, it is characterized by a high degree of lignification of the technical fiber, which is largely due to the cementing effect of lignin[11].

In addition, the fiber isolated from different areas of the stem differs significantly in chemical composition. The largest amount of lignin is contained in the fiber obtained from the basal part. In addition, a tendency to decrease in the content of pectin substances from the top to the bottom of the stem was found. The maximum cellulose content is characterized by the middle part of the stem, and the minimum is its basal part.

Low-growing oil flax has a branched stem and is very different from the tall thin and weakly branched long-stem flax not only in appearance, but also in anatomical structure. In the long-stem flax stem, the fibers are collected in wide and relatively deep (meaning the depth in the radial direction on the cross-section) bundles of regular shape. The cross sections of individual fibers have the shape of polyhedra, the cells fit tightly to each other, so the lignification of the middle plates is almost not noticeable in the places of their contact. In the stems of oil flax, the bundles of fibers are loose, with irregular serrated edges on the cross section. The cross sections of individual fibers are rounded, so they fit less tightly to each other.

The specific strength of the fiber, its ability to be divided into thin complexes and flexibility are the main properties that characterize the quality of the fibers. Length and thickness are of the greatest importance when assessing the stems as industrial raw materials. However, there are some other characteristics that make it possible to refine this assessment. Such characteristics include: branching of the stems, the degree of development of the root system, stiffness, weight, uniformity, clogging, damage.

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

It is known that branching depends on the density of the stem. Flax in thinned crops has more branched stems, in which the wood layer is well developed, but the fiber content is quite low.

The fiber content in the stems depends on the degree of development of the root system. Fig. 5 shows the root system of oil flax and long flax.

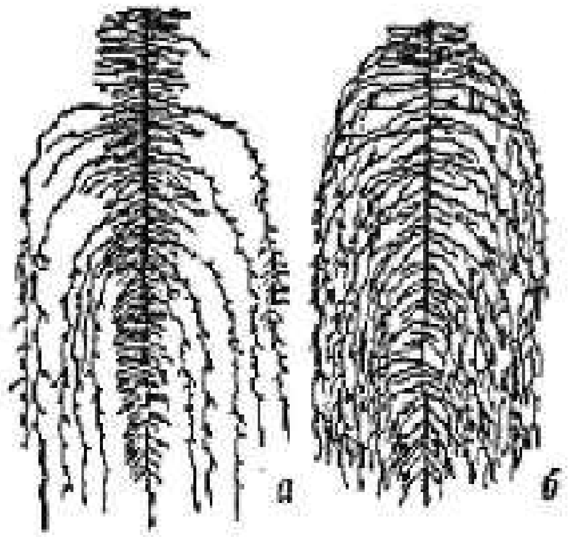

Fig. 5. Root system of long flax and oil flax:
a – long flax; b – oil flax.

Source: The relevance of developing regulatory documents for straw stalks and oil flax fiber. https://surl.gd/mwwuwg

Since the root system of oil flax is more developed, the fiber content in its stems is lower than in the stems of long flax.

The stiffness of the stems characterizes the degree of development of the wood, and therefore the fiber content in them.

The weight of the stems characterizes their structure: oil flax stems, which have a loose structure and a large internal cavity with a very developed core, are lightweight. Long flax stems have a denser structure, so they produce heavier and stronger fiber than oil flax[12,13].

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[12] Umair, M., Ullah, T., & Nawab, Y. (2023). 3D Natural Fiber Reinforced Composites in Natural Fibers to Composites. Engineering Materials. In book: Natural Fibers to Composites, 41-78. http://dx.doi.org/10.1007/978-3-031-20597-2_3.

The elementary fibers of oil flax are shorter than those of long flax due to the peculiarities of the morphological structure of this group of flax, therefore the strength of the technical fiber of oil flax is somewhat lower. Having analyzed all the above-mentioned differences in the anatomical structure and chemical composition of oil flax from long flax, we can make an important theoretical assumption: the strength of elementary fibers depends on the content of cellulose, lignin and pectin substances in them and the structure of the cell walls. As a rule, a completely non-lignified, thick-walled fibrous cell is the strongest. Along with this, the nature of the connection of the fibers between themselves and their shape in cross sections, give an idea of the strength of their connection. Both of these factors together will determine the features of the spreading process of long flax and oil flax, and therefore the quality of the resulting fiber and products made from it.

Based on the analysis of the anatomical structure and chemical composition of flax, it can be concluded that since there are significant differences between the two groups of this crop, the nature of the technological process of obtaining trusts from oil flax straw will differ significantly from the dew soaking of long flax. As a result, the technological parameters, modes and methods of obtaining trusts from long flax straw cannot be used to obtain trusts from oil flax straw.

Therefore, the development of a technology for obtaining high-quality trusts from oil flax straw for processing into fiber is an important task in conditions of a shortage of domestic raw materials for light industry.

Recently, the issue of comprehensive use of oil flax has been given great attention in many countries of the world. The current task is to use all the potential inherent in the plant: fiber, seeds and processing waste (cake, meal, coir, etc.). However, most of the technologies for processing oil flax straw developed by leading scientists in the world are suitable only for obtaining sacking, coarse fabrics, twine and tow[14].

In the USSR in 1933, the area under oil flax reached 400-500 thousand hectares, and large-scale research was carried out on the production of tow bast and its use.

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

[14] Chand, N., Fahim, M. (2021). Natural Fibers and their composites; Tribology of Natural Fiber Polymer Composites (Second Edition). Paper back ISBN: 9780128189832; eBook ISBN: 9780128190739 http://dx.doi.org/10.1016/S1369-7021(09)70093-8

Modification of tow on coarse and fine carding machines contributed to its good cleaning from smut and impurities. The length of the resulting fibers was 40-100 mm, and their average metric number was 320. This fiber and even tow after passing through the twice were suitable for the production of clothing wadding[15].

As studies have shown, the fiber from oil flax tow, obtained at enterprises with tow preparation equipment and then modified on the developed line, is suitable for the production of hygroscopic medical cotton wool according to the technology proposed by this institute. In addition, studies carried out at the Institute of Natural Fibers (Poznan, Poland) have shown that oil flax fiber can be successfully used to produce cellulose esters and all other products obtained on its basis. In Western Canada, oil flax is traditionally cultivated on 700-800 thousand hectares. The annual harvest of oil flax straw is about 1 million tons, and only 15-20% of this straw is used in production, mainly for the manufacture of cigarette paper. Pulp and paper factories are located in the states of North Carolina and New Jersey (USA)[16].·However, recently new companies have started to modify flax fiber for industrial purposes. The fiber is used as a raw material for the production of nonwovens, fiber-reinforced polymer composites, and fiberboards.

In Europe, there is great interest in the use of natural fibers (such as flax) for the production of interior panels for automobiles. The United States is starting to purchase flax fiber from Canada as an industrial material. In addition, Canada itself imports some flax straw.

In Italy, according to the Department of Economy, the yield of flax straw averages 1.5-2.5 $t{\cdot}ha^{-1}$. The straw harvested at harvest (cutting the straw 10 cm above the ground) has an average length of 28.8 cm, and the average length of the stubble left is 13 cm. The fiber obtained using the technology of the Rome Research Center (IPZS), after enzymatic treatment, spinning, active thermal ventilation and carding, is used for the production of composite materials, and the sphagnum is used for the production of boards[17].

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15 Gorach O., Dombrovska O., Tikhosova A (2021). Development of resource-saving technologies for obtaining composite materials based on the use of oilseed flax fibers Inmateh – agricultural engineering.. Vol. 65. № 3/2021. P. 275-282. https://doi.org/10.35633/ inmateh-65-29

16 The return of flax cultivation to the United States [Electronic resource]. Access mode: https://surl.gd/peimeq

17 Flax field in Astino: after more than 60 years, a dream came true [Electronic resource]. Access mode: https://www.linificio.it/en/linen-from-astino/

Thorough research on the non-textile use of flax and hemp fibers is carried out at the Polish Institute of Natural Fibers (Poznań) under the leadership of its director R. Kozlowski. Similar research is being conducted by other scientific institutions[18].

Recently, Europe and other countries of the world have shown increased interest in the use of oil flax for the manufacture of various types of products in many industries. Based on the vast world experience in the use of oil flax straw, it can be concluded that oil flax straw is a very valuable raw material. Although today it remains a secondary product, with appropriate preparation it can be used to manufacture various consumer goods. However, there is a certain technological and marketing barrier to the industrial use of straw – this is the lack of information about the physical and mechanical properties of oil flax fibers. In addition, there are still no necessary production contacts between flax straw producers and industrial enterprises that could use it. In order to compete with the currently widely used industrial fibers (glass, synthetics, sisal, etc.), it is necessary to consult with specialists who use flax fibers and know their properties.

Summarizing the above, we can conclude that only on the basis of a thorough study and analysis of the technological and morphological properties of oil flax is it possible to develop resource-saving technologies for the comprehensive use of all the potential inherent in the plant. Use of oil flax straw and its further mechanical processing to obtain fiber for various functional purposes, through the introduction and use of sufficiently effective technologies for processing oil flax straw. The development and use of new resource-saving technologies for the integrated use of oil flax stalks and seeds suitable for use in many industries is an important task of today.

2.3. Global and domestic experience in using flax oil

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 are North America, Europe and Japan. The European market is approximately 2/3 of the American market

[18] Gorach, O., Dombrovska, O., Tikhosova, A. (2021). Development of resource-saving technologies for obtaining composite materials based on the use of oilseed flax fibers Inmateh – agricultural engineering.. Vol. 65. № 3/2021. 275-282. https://doi.org/10.35633/inmateh-65-29

and is twice as large as the Japanese market. Thus, in 2012, 3.2 million tons of cotton fabrics, 6.8 million tons of nonwovens, and more than 1 million tons of knitted materials were produced for technical products, almost 11.2 million tons of products, which is 19% of the total fiber consumption in the world[19].

Currently, the scope of application of technical textiles covers more than a hundred functional objects, and new directions 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 production of non-woven materials of such types as fibrous webs, batting and geotextile materials.

Fibrous webs are pressed layers of fibers that are 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 webs, used during construction as heat-, vibration-, sound-insulating, wiping materials, etc.

Geotextile materials are composite materials, the reinforcement of which uses non-woven webs. They are used for:

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

[19] Global Technical Textiles Market Size, Share, Growth Analysis, By Material, By Manufacturing Process, By Product Form, By Application – Industry Forecast 2024-2031. https://surl.li/mkwohl

The use of such products for the manufacture of complex technical objects allows solving various target tasks and achieving high operational performance of these objects (accuracy, safety, etc.)[20].

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.

Thus, it can be concluded that the in-depth processing of oil flax straw stalks in order to obtain bast, and subsequently fiber, 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.

Leading domestic and foreign scientists L. Murphy, X. Bering, X. Wieland (Germany), R. Kozlowski (Poland), P.L. Capoletto (Italy) have proven that oil flax fiber is suitable for the production of technical textiles of various purposes[21].

In economically developed countries of the world, technical textiles made of both synthetic and natural fibers are widely used in various areas of industrial production. Currently, the world's leading machine-building companies, namely "DiloTemafa" (Germany), "LAROCHE" (France), "Charle & Co" (Belgium), etc., have developed new technological equipment for obtaining fibers from plant raw materials – long flax, oil flax, hemp, jute, nettle – and for the production of needle-punched and many other types of technical fabrics[22].

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 areas of their application in various industries. Today, presentations of new types of products and equipment for the production of technical products are held in many countries, which is a strong evidence of the high demand for technical textiles. Experts consider this indus-

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[20] Ahrari, M., Karahan, M., Karahan, N. (2023). Competitiveness Factors in Textiles and Composites Industry and Transformation into Value-Added Products. Recent – Rezult. Cercet. Noastre Teh.24, 132–141. doi:10.31926/recent.2023.70.132

[21] Karahan, M., Ahrari, M., Karahan, N. (2023). Technical Textiles Market Research and Added Value Analysis: A Regio-Global Case Study. Recent – Rezult. Cercet. Noastre Teh. 24, 162–180. doi:10.31926/recent.2023.71.162

[22] Chursina, L.A., Tikhosova, G.A., Horach, O.O., Yanyuk,T.I. (2011). Scientific foundations of complex processing of stalks and seeds of oil flax. Monograph. Kherson: Oldiplu. 356 p. https://surl.gd/zkdukm

try to be one of the five most high-tech sectors of the world industry with high development potential. That is why restructuring is underway in the textile industry – many companies are betting on the production of technical textiles, thereby choosing:

- more sustainable and less competitive areas of global production (new textile products for various industries);
- more reliable placement of investments in goods with high added value and more flexible service and logistics to ensure optimal asset management in crisis situations.

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 – oilseed 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.

In economically developed countries of the world, the production volumes of technical textiles are constantly growing. Thus, currently, this sector of the French economy employs from 300 to 370 companies (17% of the entire textile industry of the country). They provide jobs for 21,000 people (25% of all workers employed in the textile industry of the country) and produce 700 thousand tons of textile products per year. The total annual turnover is 3.3 billion EUR (27% of the turnover of the entire textile industry). The products of the technical textile sector account for 33% of all textiles exported by France. Among the companies engaged in this sector of the country's economy, the largest share falls on manufacturers of textile products (31%), yarn and technical fabrics (27%). The shares of manufacturers of technical knitwear are much smaller – 8.1%, chemical products for the sector – 6.5%, special clothing – 6.0% and textile equipment – 5.4%. The remaining 16.0% produce a wide range of products, respectively, their shares in the market structure are minimal.

850 companies (42 thousand employees) are associated with the technical textiles sector in Italy, of which 300 (15 thousand jobs) are engaged only in technical textiles. Annual turnover is 3.2 billion EUR, annual exports of products amount to 1.25 billion EUR. The sector's share in the country's textile industry is 8%. Companies specialize mainly in the production of protective textiles for special-purpose clothing, as well as transport and interior textiles[23].

In Turkey, before the economic crisis, the textile industry was formed by about 30 thousand companies, 90% of which were small and medium-sized. However, only 150 of them were employed in the technical textile sector. Technical textile exports (1.39 billion USD/year) and imports (1.24 billion USD/year) in the country are more or less balanced. Despite the crisis, Turkey is becoming one of the major players in the global technical textile market with a domestic market capacity of over 1.5 billion USD. Turkish companies produce mainly interior textiles for the hotel industry, protective, transport, agricultural textiles and export them to the USA, EU countries and Russia for about 900 million USD annually. In addition, Turkey plays an increasingly significant role as an importer of technical textiles, exporting them mainly from Germany, Italy, China, the Czech Republic, South Korea, Israel, Japan and India for up to 700 million USD/year.

The rapid growth of the Indian economy is evidenced, in particular, by the positive dynamics of the country's textile industry. It grew by 275% in the period 2001-2007 alone. The reasons for the stability of the Indian economy during the global crisis lie in its relatively weak dependence on exports, including in the textile industry. Indian textiles provide 4% of the country's GDP and employment for about 85 million people. At the same time, the country needs to solve a number of problems to ensure the competitiveness of products from the technical textile production sector.

According to IFAI, the structure of the American textile market has undergone significant changes over the decade (1998-2008). While maintaining a constant share of home textiles (37%), the share of clothing decreased from 38% to 20%, and the share of technical textiles increased from 25% to 43%. Currently, about 7,000 companies are engaged in technical textiles (of which 1,500 are suppliers, manufacturers of semi-finished products, raw materials

[23] Horach, O.O. Dombrovska, O.P. (2021). Use of oilseed flax and hemp in the food industry Bulletin of the University of Trade and Economics. Lviv. Publishing House of the University of Trade and Economics, 2021. Issue 28. P. 18-22. https://doi.org/10.36477/2522-1221-2021-28-03

and service companies, 5,500 are manufacturers of final products). In 2008, 1.56 million tons of nonwovens were produced in the USA. Some of them were exported, with the largest deliveries to Asian countries (56,893 tons), while imports from Asian countries this year amounted to 80,849 tons[24].

The main growth trends in the technical textile market are primarily associated with high-tech textiles of the new generation, the production of geosynthetic materials, environmental, medical and protective textiles (mainly for the needs of the military department).

In Canada, 118 out of 400 textile companies have chosen the production of technical textiles as a business that guarantees a fairly high added value. In total, the Canadian textile industry employs more than 40,000 people. The industry's enterprises work in the areas of hybrid technologies (warp knitwear and nonwovens), the creation of "smart textiles" based on the application of nanotechnological and biotechnological treatments, the use of special high-performance fibers. Up to 82% of these products are exported to the USA.

The sixth place in the top ten largest global suppliers of textile products is occupied by South Korea. The industry structure optimized over 60 years and highly developed information technologies allow directing joint efforts of business and the state to develop new generation textile products based on the symbiosis of textile, bio-, nano– and IT-technologies. For this purpose, the Ministry of Education and Economy allocated 20 billion KRW (11.63 million EUR) under a special program that started in April 2009. 7 more billion KRW (over 4 million EUR) is invested in scientific research and development and development of combined fibers and nanotextile products. It should be noted that the total amount of investment support fund for South Korea's processing industries from the budget and large corporations is 73.5 billion KRW (42.76 million EUR). In addition, the municipality of Daegu (2.5 million inhabitants, the center of the Korean textile industry) allocates 200 billion KRW (116 million EUR) to implement a five-year plan for the development and production of textile products based on aramid and carbon fibers for use in semiconductors, batteries and high-precision filters. The structure of the textile industry in Taiwan (a total of 5,000 enterprises providing 186 thousand jobs) currently consists of clothing production (60%), textiles and textile products (30%), and chemical fibers (10%).

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24 Bayar, G. (2022). Türkiye's sectoral exports: A competitiveness approach. International Journal of Finance and Economics, eISSN 2146-4138, Vol. 27, 2268-2289. https://doi.org/10.1002/ijfe.2272

The reorientation of priorities, with which the development prospects are associated here, consists, first of all, in the transition from mass industrial production to the production of products with high added value, in particular, environmentally friendly medical, functional and "smart textiles", which will contribute to energy and resource conservation. The projects of the Taiwan Textile Research Institute (TTRI) include work on the development of textile nanoproducts, new chemical and artificial fibers, industrial and medical textiles.

The economic programs of the Chinese government are aimed at the development of infrastructure (about 390 billion EUR allocated for the expansion of the network and modernization of railways, the construction of subways in the largest cities, the construction of 50 new airports and the reconstruction of 90 existing ones), environmental protection and health care (about 21 billion EUR).

Both of these areas are related to the needs for technical textiles. The China Nonwovens and Industrial Textiles Association (CNITA) has identified four "success factors" for technical textile enterprises that have achieved high results: equipping production with the latest technological lines; mastering new high technologies; developing or releasing innovative products; producing dual-purpose products that are both in demand on the commodity market and supplied under state orders[25].

According to experts' forecasts, the volume of textile imports will increase. It is assumed that the need for textile products will grow due to imports by 30-40% annually. It should be noted that 90% of this growth will fall on the technical textile sector, since at present the demand for it is satisfied by only 17%. This is explained by the fact that Russian manufacturers cannot compete in the domestic market due to:

– technical backwardness of production (a significant part of the technological equipment park has been used for over 20 years);
– the need for large-scale investments in the development of the industry; conflict of interests: according to the government, the technical textile sector should develop not to meet the needs of industries that ensure the development of the country's infrastructure, but in the direction of pro-

[25] Karabay, G. & Sarıçoban, K. (2021). Research on Competitiveness in Technical Textiles: Comparison of Countries Having the Lion's Share of Technical Textile World Exports and Türkiye. Fibres and Textiles in Eastern Europe, eISSN 2300-7354, Vol. 29, is. 6(150), 22-31, http://dx.doi.org/10.5604/01.3001.0015.2718

ducing a narrow range of products, for example, technical textiles with innovative nano-coating.

According to industrial markets, bleached cellulose and bicomponent staple fibers are required for the production of new generation technical textiles. Scientists have developed and adopted a program for the production of medical textiles and disposable hygiene products. The production of these products also requires environmentally friendly cellulose-containing raw materials with appropriate physical and mechanical characteristics[26].

In Germany, the share of technical textiles has reached almost 50% of the total textile production. This was the result of the implementation of the economic program of the German government to support the development of domestic demand for geotextiles and industrial textiles. It should be noted that German enterprises are leading manufacturers of automotive textiles.

In general, the analysis of the German and world markets for these products indicates their significant differences. Germany dominates in the field of manufacturing textile materials for transport construction (Fig. 6), medicine, sports and industrial purposes, while in the whole world the production of textile products for agricultural, geotextile (Fig. 7) and construction purposes is developing faster (compared to Germany) (Table 4).

Fig. 6. Car interior floor mat made of non-woven materials

Source: Natural Fiber Composites: An Overview https://www.kompozit.com/post/natural-fibre-composites-an-overview

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26 Park, H. (2022). The Current State of the Korean Technical Textile Industry and Tasks for Policy. KIET Industrial Economic Review, ISSN 1598-947X, Vol. 27, is. 2, 19-29, Paper № 22/IER/27/2-2. http://dx.doi.org /10.2139/ssrn.4190717

Fig. 7. Creation of an anti-filtration screen using geotextile material during the construction of a landfill for waste storage

Source: Natural Fibres: A Sustainable Material for Geotextile Applications Indian Geotech J https://doi.org/10.1007/s40098-023-00862-w

Table 4. Structure of consumption of technical textiles

Technical Textile Groups	Consumption volumes,%	
	Germany	world market
Agrotextiles	7	12
Construction Textiles	10	15
Geotextiles	3	9
Industrial Textiles	18	16
Medical Textiles	13	10
Transport Textiles	22	17
Packaging Materials	5	6
Protective Textiles	10	7
Sports Textiles	12	8
Total	100	100

Source: History, technology and types of technical textiles https://surl.gd/rkyonn

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.

Thus, 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.

In general, 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[27].

At the end of the 20th century, clothing and home textile manufacturing enterprises moved to Southeast Asian countries due to the availability of cheaper labor in this region. Europe and the USA focused on developing more complex and science-intensive technical textiles. In the USA and Western Europe, the share of technical textiles is 40% of production and consumption, and in China – 20%. The results of a study of changes in the volume of consumption of technical textiles in different regions of the world are presented in Table 5.

Table 5. Dynamics of the use of technical textiles in different regions of the world

Region	Volumes of use, thousand tons			
	2005 y.	2010 y.	2015 y.	2020 y.
North America	3584	4184	4774	5591
South America	705	874	1004	1230
Western Europe	3002	3614	4107	4760
Eastern Europe	493	548	666	817
Asia excluding China	3895	4449	5220	6348

27 Shahata Hassan, N., Ahmed, Sadek M., Said, Shamandy, E. (2019). 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. eISSN 2357-0342, is. 19. https://doi.org/10.21608/mjaf.2019.13553.1198

Region	Volumes of use, thousand tons			
	2005 y.	2010 y.	2015 y.	2020 y.
China	1515	2155	2871	3808
Other countries	778	917	1014	1219
Total	13972	16741	19656	23773

Source: Classification of technical textiles – the path to quality and safety of goods https://surl.gd/mrlnmj

Based on the data in Table 4, it can be concluded that the countries of Asia, North America and Western Europe are the largest consumers of technical textiles in the world. The total amount of technical textiles used in Asian countries in 2020 exceeded 10 thousand tons. The volume of consumption of technical textiles from 2010 to 2020 in North American countries increased by 56.0%, and in China and other Asian countries by 87.7%. It should be noted that in the use of technical textiles, the countries of Eastern Europe, including Ukraine, lag significantly behind all regions of the world. The volume of use of technical textiles in Eastern Europe is 12.4 times less than in Asian countries and China and 5.8 times less than in Western Europe[28].

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 through the use 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. Reinforcement of composite materials can be carried out with oriented or unoriented (entangled) fiber and nonwoven materials obtained from it, yarn or even fabric. If a nonwoven material or fabric is used, the composite is formed in the form of a sandwich or pressed, located inside a layer, for example, polypropylene (Fig. 8 a). This results in a very strong, unbreakable structural material. The fiber or bast

[28] Holderied, P., Mutschler, T., Tresp, S., et al. (2023). Development of a new yarn supply for weft knitting machines to produce innovative knitwear. Communications in Development and Assembling of Textile Products, ISSN 2701-939X, Vol. 4, is. 1, 51-60, https://doi.org/10.25367/cdatp.2023.4.p51-60

is inside the polypropylene, that is, they are protected from the environment and are not subject to biological destruction.

Flax fiber material can be used to reinforce structural polymer 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 obtained in the processes of casting, extrusion (Fig. 8 b) or pressing. Glass fiber, used in our time in composite polymer 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 (Fig. 8 c).

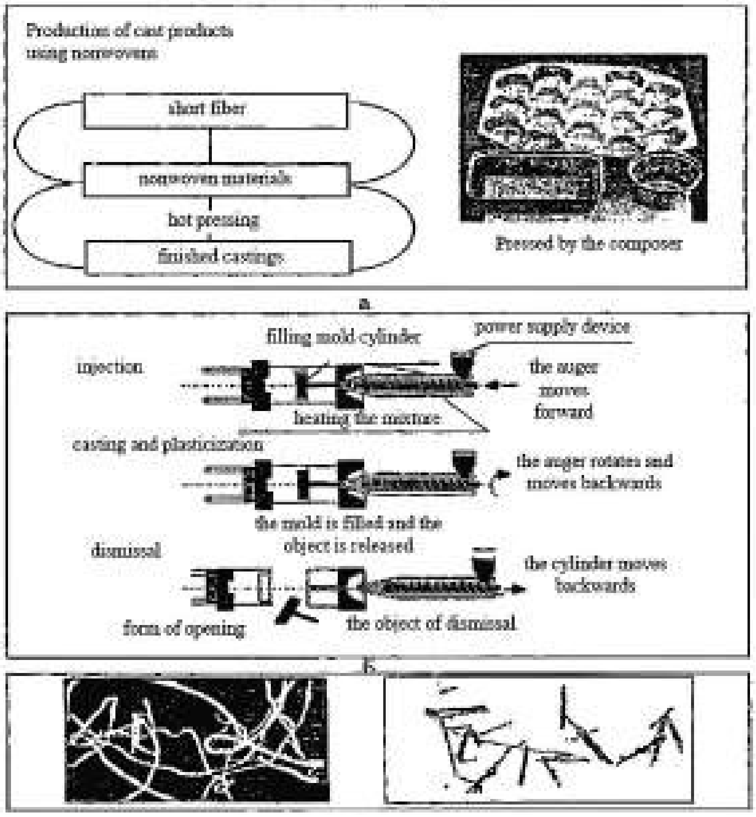

Fig. 8. Reinforced composite materials: a – production of composite materials reinforced with non-woven materials from flax;
b – injection molding; c – fiber obtained from injection molding;
on the left – flax, on the right – glass

Source: Natural Fiber for Geotechnical Applications: Concepts, Achievements and Challenges. https://www.mdpi.com/2071-1050/15/11/8603

In composite polymer materials, where flax fiber is used as a reinforcing material, the range of polymers used is limited. The fact is that at high temperatures (220°C) pyrolytic decomposition of flax fiber may begin. Therefore, polyolefins are most often used for this purpose, which have lower softening points than other polymers.

Composite materials reinforced with plant fibers are most widely used in the automotive industry. In this case, various natural fibers can be used to reinforce structural polymer materials: flax, hemp, jute, sisal, coconut. In countries with a developed automotive industry, these materials are usually imported. Strong, corrosion-resistant, lightweight polymer composites are increasingly used in cars. In modern cars, they account for more than 10% (by weight) and their content is constantly increasing[29].

The pioneer of the use of plastics in the automotive industry was Henry Ford in 1941. In 1953, Chevrolet manufactured many parts from polypropylene materials reinforced with various fibers. This allowed to reduce the weight of the car by 85 kg. In 1991-1992, plastics accounted for 149 kg of the car's weight (or 10.1%) in BMW. The first bumper was manufactured by Ford in 1968. Renault in 1971 manufactured a polyester bumper reinforced with fiberglass. A polypropylene bumper reinforced with natural vegetable fiber was installed by Fiat in its 126 and 128 models. Natural vegetable fibers are also used in various structural elements of the Daimler-Benz car (Fig. 9). Reinforcing plastics with natural fibers, such as flax fiber, significantly simplifies the recycling of parts that have reached the end of their useful life, compared to fiberglass reinforcement[30].

[29] Azam, F., Ahmad, F., et al. (2022). The Role and Applications of Aerogels in Textiles. Advances in Materials Science and Engineering, eISSN 1687-8442, Vol. 2022. https://doi.org/10.1155/2022/2407769

[30] Chursina, L.A., Tikhosova, G.A., Horach, O.O., Yanyuk,T.I. (2011). Scientific foundations of complex processing of stalks and seeds of oil flax. Monograph. Kherson: Oldiplu. 356 p. https://surl.gd/zkdukm

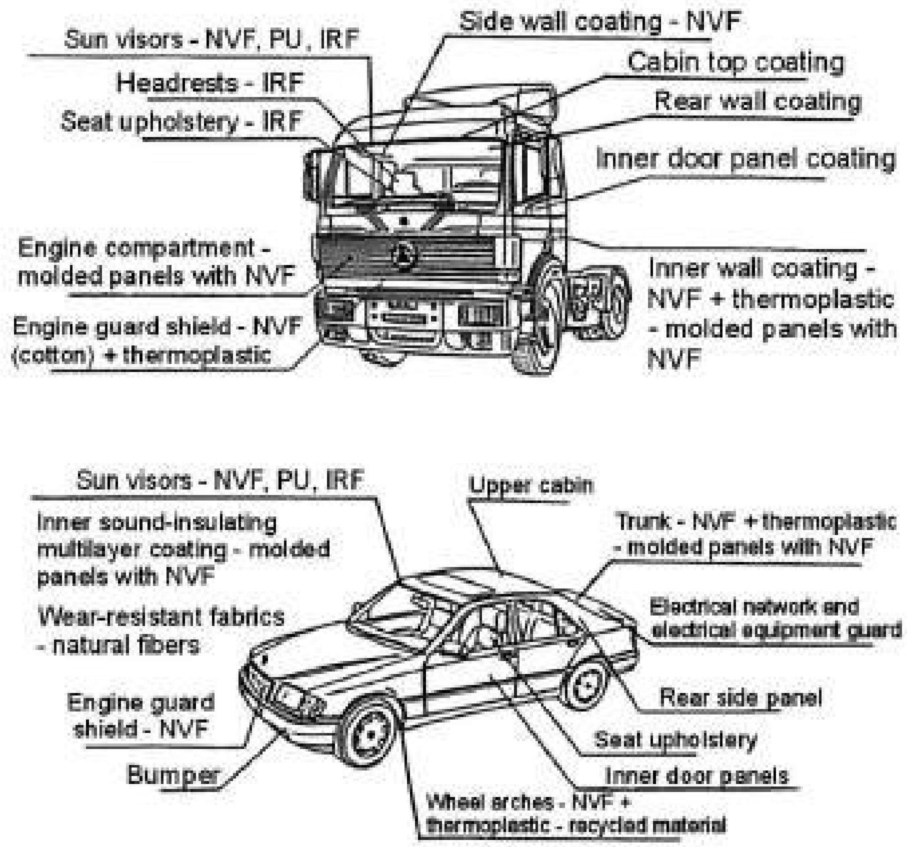

Fig. 9. The use of natural vegetable fibers in various structural elements of the Daimler-Benz car (NVF – natural, vegetable fibers, PU – polyurethane, IRF – India rubber fibers)

Source: The use of natural plant fibers in various structural elements of the Daimler-Benz car. https://surl.li/xtfjhw

The strength characteristics of the fiber used for reinforcement are given in Table 6.

Table 6. Strength characteristics of the fiber used for reinforcement

Fiber	Density, g/cm	Diameter, µm	Elongation at break, %	Modulus E,%	Ultimate strength, g/tex	Moisture content, %	Permissible molding temperature, °C
Cotton	1,20	11-22	7	500	0,8	7	220 destructive
Linen	1,30	5-40	3	1840	1,3	7	
Jute	1,50	8-30	2	1750	0,5	12	
Sisal	1,45	8-40	2	2500	0,5	8	
Glass	2,55	5-24	2-5	3000	1,0	1	800
Hydrocarbon	1,90	5-7	2	10000	10,0	1	1200

Source:. Verification of material characteristic of natural fibers for concrete reinforcement. https://surl.gd/lihqlw

The relationship between the load and elongation of reinforcing fibers and similar relationships for finished composite materials with different flax fiber contents and without the use of fiber are shown in Fig. 10, 11.

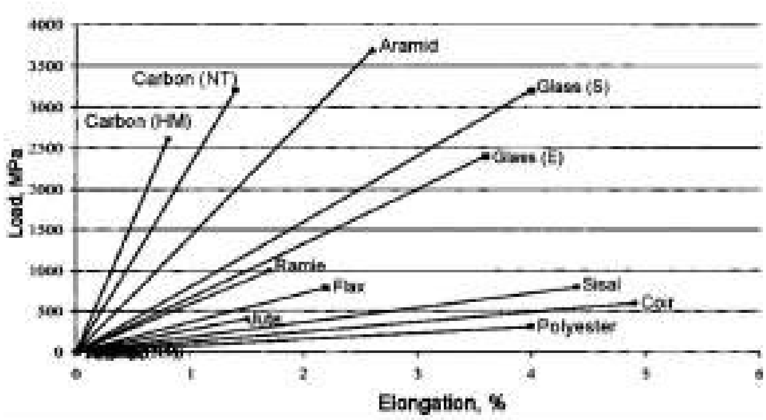

Fig. 10. Relationship between load and elongation of reinforcing fibers and unsaturated polyester resin

Source: Development of resource-saving technologies for obtaining composite materials based on the use of oilseed flax fibers Inmateh – agricultural engineering https://surl.li/escnwn

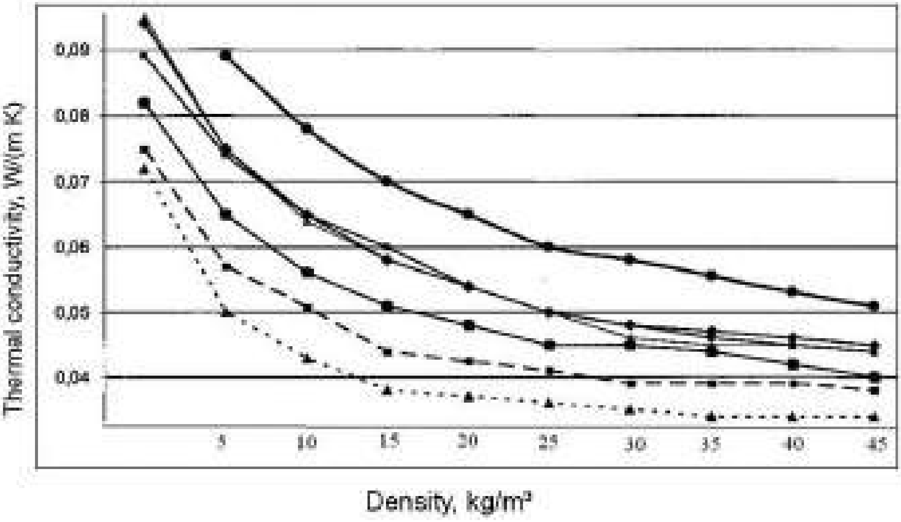

Fig. 11. Dependence between load and elongation of composite materials with plant fibers according to Folster and Micheli: a – epoxy resin + flax (55% flax by volume); b – flax, sisal with polypropylene; c – polyester + flax; d – polypropylene + flax (30% by volume); e – polyester + jute; f – epoxy resin without fiber; g – polypropylene without fiber

Source: Development of resource-saving technologies for obtaining composite materials based on the use of oilseed flax fibers Inmateh – agricultural engineering https://surl.li/escnwn

The use of natural fibers, in particular low-grade long-flax fiber, as well as oil flax fiber in composites for the automotive industry in the CIS countries is still at the stage of research and development.

Analyzing the world experience in the use of flax fibers to obtain reinforced materials, we can conclude that oil flax fiber, having the 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 fasteners.

An important area of use of oil flax fiber is the production of nonwoven materials. In many countries, extensive experience in the production of nonwoven materials from various fibrous waste and low-grade long-flax fiber has been accumulated. The production of nonwoven materials from long flax fiber involves the use of waste from the spinning process and short fiber after processing on the fiber separating machine fiber separating machine[31].

Unfortunately, Ukraine has not developed a technology for the production of nonwoven materials from oilseed flax fiber. However, the experience of scientists from different countries in the use of oilseed flax fiber to produce nonwoven materials can be used at domestic enterprises. Scientists from the German Institute of Agricultural Construction and the Federal Agricultural Research Center (L. Murphy, X. Bering, X. Wieland) studied the thermal insulation properties of nonwoven fabrics of different densities (Fig. 1.7) 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 glass wool fabrics, then fabrics made of coarse fibers provide the necessary thermal insulation only with their high density. At the same time, in the range of low density (10-20 kg/m3), 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/m3, and coarse bast fiber sheets will have a thermal conductivity of only 25-40 kg/m3. Therefore, as the density of nonwoven materials increases, their thermal conductivity decreases. If nonwoven materials are used for thermal insulation, then during their manufacture it is necessary to use a thinner fiber and produce a material with a density of at least 35 kg/m3, which is sufficiently breathable. For this purpose, the most suitable is oil flax fiber (Fig. 12).

[31] Azam F., Ahmad F., et al. (2022): The Role and Applications of Aerogels in Textiles. Advances in Materials Science and Engineering, eISSN 1687-8442, Vol. 2022. https://doi.org/10.1155/2022/2407769

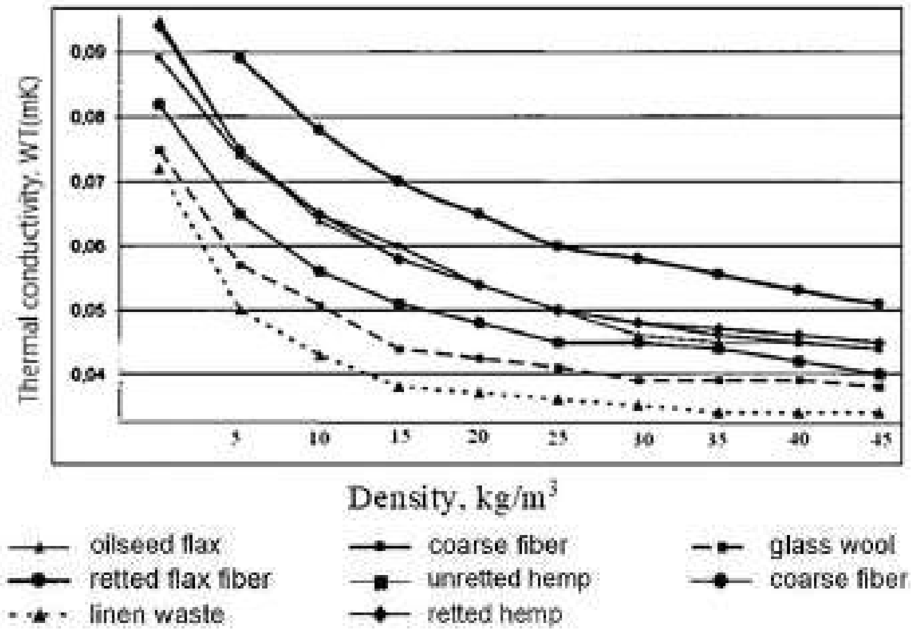

Fig. 12. Dependence of thermal insulation properties of nonwoven materials made from different raw materials on their density

Source: Development of resource-saving technologies for obtaining composite materials based on the use of oilseed flax fibers Inmateh – agricultural engineering https://surl.li/escnwn

Further increase in the density of these materials almost does not reduce thermal conductivity and only leads to an increase in the mass of the material, and a decrease in density causes a significant increase in thermal conductivity. This fully corresponds to the well-known definition of fiber thickness by air permeability (airflow). Nonwoven materials of the same density, but with a lower (due to the greater thickness of the fiber) resistance to air passage, have a higher thermal conductivity.

Summary of world and domestic experience in the manufacture of technical textiles from oilseed flax fibers (Fig. 13)[32].

[32] Emmanuella, K.T. (2022). A Comparison of financial performance in textile industry: KPR Mill Ltd vs Arvind Ltd. Business dissertation report, Pandit Deendayal Energy University, School of Petroleum Management, Gandhinagar, Gujarat, India, http://localhost:8080/xmlui/ handle/123456789/539

Technical textiles are usually made from chemical fibers (viscose, polyester, polyamide, polypropylene, etc.). The proportion of natural fibers (linen, jute, coconut, cotton, wool) used in the manufacture of these materials does not exceed 23%.

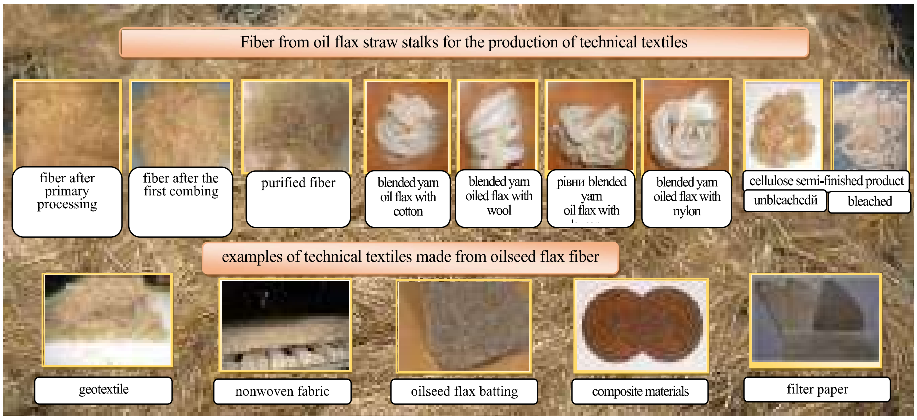

Fig. 13. Samples of technical textiles made from oilseed flax fibers

Source: The latest comprehensive systems for assessing the quality and processing of flax-containing materials chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/ https://lib.lntu.edu.ua/sites /default/files/2024-02/MONOGRAFIA.pdf

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, 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 of various functional purposes, is an urgent scientific and technical problem.

2.4. Application of oil flax fiber for the production of technical textiles

The global market for technical textiles, which at the beginning of the 21st century was estimated at 120 billion US dollars per year, is characterized by a tendency to constant growth, as new areas of application for technical materials appear. Experts claim that there are practically no limits for this sub-sector of light industry and it develops in parallel with all other industries. According to experts, in 2020 the global market for technical textiles grew to 193 billion US dollars, while the volume of the global market for technical textiles in 2015 was about 155 billion US dollars[33].

According to the study "Technical Textile Market: Global Industry Analysis and Opportunity Assessment 2015-2020" by Future Market Insights, the largest market for the production and consumption of technical textiles in the world today is the Asia-Pacific region. This region is home to the two most densely populated regions of the planet, and textile production is one of the main sources of jobs for the local population. High demand for technical textiles forces manufacturers to invest in research and development activities and increase production volumes. In 2015, the Asia-Pacific region occupied almost 40% of the global technical textiles market in monetary terms. According to forecasts by experts in the field of technical textiles, this dominance will continue until 2025. Two other profitable markets for the technical textiles industry are Western Europe and North America. The leading manufacturers of this product are: Polymer Group Inc., Ahlstrom Corporation, DuPont Chemicals Company, Freudenberg & Co.KG, TWE Group.

The analysis of literature sources indicates the growth of global production volumes and use of technical textiles. The dynamics of changes in de-

[33] Mushtaq, B., Ahmad ,A., Ali Z., et al. (2022). Core Spun Based Helical Auxetic Yarn: A Novel Structure for Wearable Protective Textiles. Journal of Natural Fibers, ISSN 1544-0478, Vol. 19, is. 16, 15058-15070, https://doi.org/10.1080/15440478.2022.2070322

mand for technical textiles in almost all industries of modern production are presented in Table 7.

Table 7. Dynamics of the use of technical textiles in 2005-2020 y.

Areas of application	Volumes of use, thousand tons			
	2005 y.	**2010 y.**	**2015 y.**	**2020 y.**
Agriculture	1173	1381	1615	1958
Construction	1261	1648	2033	2591
Workwear	1072	1238	1413	1656
Geotextiles	196	255	319	413
Furniture	1864	2186	2499	2853
Industry	1846	2205	2624	3257
Medicine	1228	1543	1928	2380
Vehicles	2117	2479	2828	3338
Packaging	2189	2552	2990	3606
Technical protection	184	238	279	340
Sporting goods and equipment	841	989	1153	1382
Total	13971	16714	19681	23774

Source: Classification of technical textiles. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/ http://tr.knute.edu.ua/files/2018/02(26)/7.pdf

Analysis of Table 6 shows that the greatest demand is for technical textiles for the production of packaging materials – 3606 thousand tons, and the least technical textiles are used for technical protection and environmental protection – 340-413 thousand tons. Thus, we can conclude that in the future technical textiles will be widely used in various branches of modern production. However, in Eastern European countries, the development of the industry for the production of technical textiles requires great attention and thorough scientific research[34].

[34] Cardoso, A.C. (2021). Potencial de própolis no desenvolvimento de têxteis com propriedades funcionais (Potential of propolis in the development of textiles with functional properties). Master thesis, Universidade do Minho, Brasil, Dissertacao-PG37988.pdf, https://hdl.handle.net/1822/79512

The areas of application of technical textiles are practically limitless. It is difficult to find a branch of economy or sphere of human life, wherever textile technical materials are used.

In our opinion, 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.

In 2016, 66.8 thousand hectares were allocated for sowing this crop in Ukraine. In economically developed countries of the world – Canada, Belgium, France, Germany – there is extensive experience in using seeds, straw, trusts and oil flax fiber to create environmentally friendly products, which are widely used in various areas of industrial production. 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[35].

The smut content 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.

If the fiber is prepared using existing technologies on the "LAROCHE" line for the purpose of producing paper pulp, then it should have a smut content within 1-25%. The cost of such fiber with a smut content of 25% on the European market is 300 euros per ton. Thus, the lower the smut content, 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.

At present, the cost of oilseeds on the international market is on average 1000 euros per ton. The use of modern advanced technologies will allow the

[35] Fiber processing equipment [Electronic resource]. Access mode: https://www.textiletech nology.net/ news/news/Laroche-Fiber-processing-equipment-13595

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.

The literature review conducted on the topic of the dissertation allows us to conclude that the importance of technical textiles is difficult to overestimate, since its areas of application are practically limitless. However, until recently, there was no generally accepted classification system for technical textiles and nonwovens in the world. Yes, each country had its own approach to what products should be classified as technical textiles. Until 1993, Western European countries did not have a single classification of technical textiles. Creation of the European Union has intensified work on developing a unified system for classifying and accounting for technical products. One of the principles of classification can be considered division by the composition of the raw materials from which the products are made. This classification is based on the origin of the fibers (natural or chemical) used to produce the material. Another principle was proposed by the organizers of the largest international exhibitions of technical textile products – the company "Messe Frankfurt"[36]. This classification was based on the following criterion: the purpose of technical textiles.

According to the areas of use, technical textiles were divided into 12 categories:

– agrotextiles (Agrotech, for agriculture);
– construction (Buildtech, for construction);
– household (Hometech, for household use);
– industrial (Indutech, for industry);
– sports (Sportech, for sporting goods);
– packaging (Packtech, for packaging materials);

[36] Techtextil i Texprocess 2022 [Electronic resource]. Access mode: https://surl.li/cyrgaz

- transport (Mobiltech, for transport, automotive and aircraft construction);
- medical (Meditech, for medicine);
- clothing (Clothtech, for clothing production);
- geotextiles (Geotech, geotextiles);
- protective (Protech, for protective equipment);
- ecotextiles (Oekotech, for environmental protection).

Such areas of application of technical textiles as industrial, packaging and transport provide the highest income from the sale of this type of product. Thus, in 2015, the total income of manufacturers of industrial and packaging textiles was almost the same and amounted to 21.8 billion US dollars for each of both product groups, and the total volume of technical transport textiles was estimated at 20.7 billion US dollars. According to expert forecasts, by 2030 the highest average annual growth rates should be shown by such new types of technical textiles as eco-textiles, geotextiles and sports textiles.

Eco-textiles are technical textiles for use in the environmental protection sector and the recycling of industrial waste, which are very popular in the world due to the growing attention to the rational use of natural resources. In the future, by 2030, eco-textiles should show the highest average annual growth rate of production volumes – up to 4 billion US dollars.

Geotextiles are technical textiles for engineering and geological purposes, used during the construction of roads and bridges, to strengthen rail tracks, road slopes, etc. According to expert forecasts, by 2030 the average annual growth rate of this sector of technical textile production will reach 6%. Sports textiles are technical textiles used for the production of various artificial sports surfaces, fishing gear, parachute fabrics, etc. It is expected that due to the high demand for sports textiles, this market segment will have an average annual growth rate of 5.5% by 2020.

By type of production processes, technical textiles are divided into nonwoven, composite and other (knitted, woven, woven). Nonwoven technical textiles are in the greatest demand in the world. In 2015, its total volume was estimated at more than 80 billion US dollars. In the future, if the growth in this market segment is maintained, by 2030 nonwoven technical textiles will have the highest average annual growth rates and will retain a larger market share.

It should be noted that not all industry experts agreed with the above classification. The members of the European Technical Textiles Club (ETT Club) have decided to classify only 9 market segments for technical textiles instead of the 12 defined fifteen years ago by the exhibition company Messe Frankfurt [37]. According to this classification, technical textiles are divided into:

- agrotextiles;
- geotextiles;
- construction textiles;
- industrial textiles;
- medical textiles;
- automotive textiles;
- packaging textiles;
- protective textiles;
- textiles for the production of sportswear and accessories.

Specialists from leading industries (machine-building, chemical, automotive, aviation, construction, packaging) together with 16 German textile institutes carry out all the necessary research and development work to improve manufacturing technologies and expand the range of technical textiles in Germany. As a result of this cooperation, many innovations and promising developments of innovative types of technical textiles have been introduced into production. Thanks to the cooperation of industrial enterprises and research and development organizations, the production of technical textiles is constantly growing in all segments of the commodity market.

Currently, in the EU and the USA, the concept of technical textiles includes all materials that are not used directly for the production of household clothing, bed linen and interior items.

In the USSR, only heavy technical fabrics and technical silk were considered technical textiles, and products for the production of uniforms and ammunition for law enforcement agencies, protective and sportswear, etc. were never considered to be part of this group of products. Today. Various types of these products are distributed in the following ratio: fabrics for rub-

[37] Mezrea, P.E., Ispir, M., Balci, I.A., et al. (2021). Diagonal tensile tests on historical brick masonry wallets strengthened with fabric reinforced cementitious mortar. Structures, eISSN 2352-0124, Vol. 33, 935-946, https://doi.org/10.1016/j.istruc.2021.04.076

ber and technical products – 59.75%; fabrics for the tire industry – 6.09%; filter fabrics – 7.45%; fabrics for mine ventilation pipes and awnings – 13.16%; non-woven materials – 11.59%; other fabrics – 1.96% of the total volume of technical textile production.

As already noted, Western experts classify technical textiles only by areas of application. It is this difference in classification that led to the fact that in the USSR the share of industrial fabrics in 1990 was only 1/12 of the total volume of textiles produced in the country. At the same time, in the developed countries of the world it was equal to: 1/3 in the USA, 1/4 in Japan and Germany[38].

Technical textiles are also classified by production technology (Table 8). Traditionally, technical textiles were divided into only two categories: fabrics (all products for technical purposes) and nonwovens. Japanese specialists, when classifying, pay attention to production technologies and types of raw materials used to manufacture this group of goods.

Table 8. Distribution of technical textile materials by technology and production volumes

Material Type	Share in EU countries,%
Fabrics	37,0
Nonwoven Fabrics	27,0
Combined	16,0
Other	20,0

Source: Problems of forming composite materials reinforced with bast fibers. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://journals.indexcopernicus.com/api/file/viewByFileId/1182909

The share of technical textiles produced from chemical fibers and yarns in the EU countries is more than 2 times higher than the volume of fabric production. For example, in Germany, when classifying technical products, only the areas of application of technical textiles are taken into account. Japanese colleagues pay primary attention to production technologies and types of raw materials used to manufacture this group of goods. Recently, there

[38] Official Website of the International Trade Administration [Electronic resource]. Access mode: https://www.trade.gov/sites/default/files/2020

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 nonwoven materials in our country is significantly lower than the growth rate of imports[39].

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 accordance with the amendments made by the Laws of 24.12.2015 No. 909-VIII, of 04.10.2016 No. 1645-VIII, of 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[40].

In Ukraine, there are practically no government programs to support and develop the textile and light industry, as well as the production of raw materials for it. There is no general information and analytical center for light industry, no one carries out detailed statistical accounting of output volumes and other economic indicators of enterprises. Classification, as a method of commodity science, will allow systematizing the entire variety of modern goods on the world market. The presence of a clear classifica-

[39] International Trade Administration [Electronic resource]. Access mode: https://www.trade.gov/get-ndustry-updates-textilesapparel

[40] Law of Ukraine № 2697-IX On the Customs Tariff of Ukraine [Electronic resource]. Access mode: https://zakon.rada.gov.ua/laws/show/2697-IX#Text

tion of goods according to certain characteristics will allow limiting access to the domestic market of potentially dangerous products.

Based on the results of the analysis, an expert survey conducted at enterprises manufacturing 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:

1. Scope of application: textiles for agriculture; construction textiles; textiles for the production of footwear and ammunition; geotextiles (textiles for earthworks); textiles for the home; industrial textiles; medical textiles; textiles for mechanical engineering; environmental protection textiles; packaging textiles; sports textiles and textiles for tourism and recreation.
2. Types of raw materials: natural fibers, synthetic fibers, glass fibers; metal fibers; basalt and carbon fibers; other fibers.
3. Production technology: woven materials, woven, knitted, knitted products; non-woven materials (filtering, insulation, fillers, absorbers, bases for other industries and other materials); coated textiles; textiles with additives.

In this regard, based on the analysis of existing approaches to the classification of technical textiles in the world, the work identifies the main criteria by which technical textiles in Ukraine could be classified. We have proposed a hierarchical classification of technical textiles, which is presented in Fig. 14.

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 of this subsector, the presence of a clear classification is extremely important.

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[41].

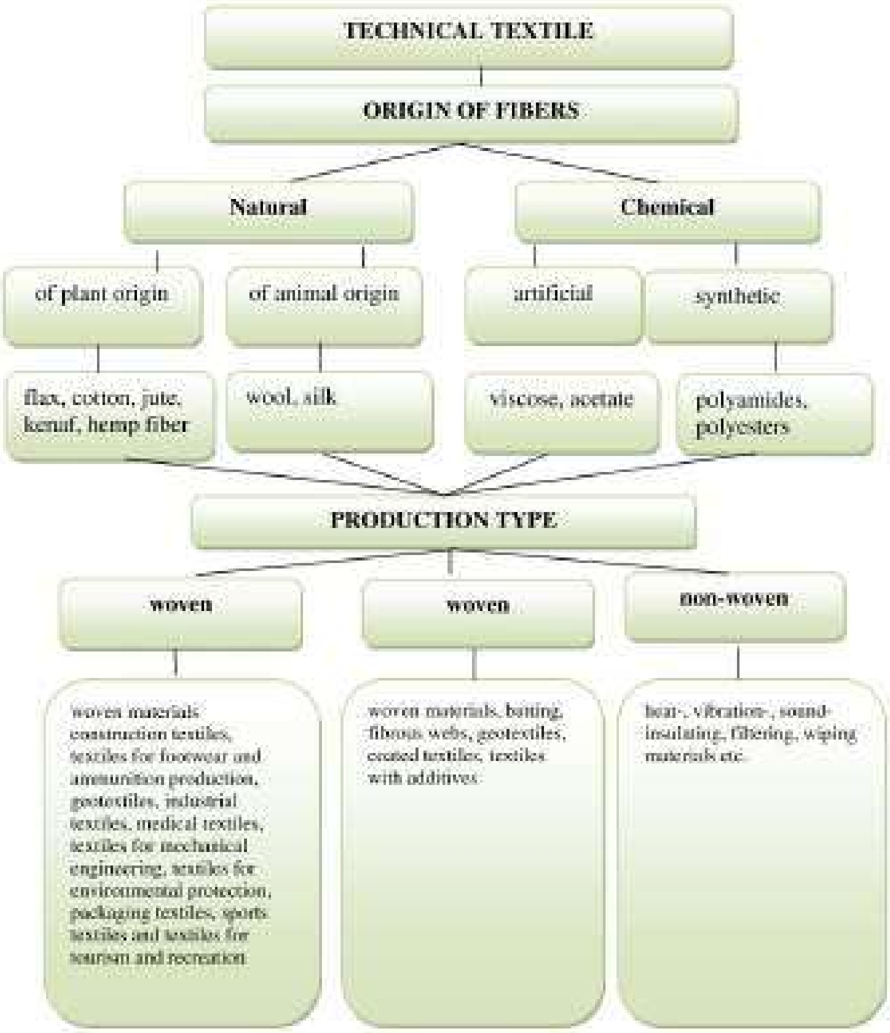

Fig. 14. Classification of technical textiles

Source: Classification of technical textiles. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/ http://tr.knute.edu.ua/files/2018/02(26)/7.pdf

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41 Chursina, L., Gorach, O. (2020). Classification of technical textiles – the path to quality and safety. Collection "Scientific Bulletin of the Poltava University of Economics and Trade" series "Technical Sciences" №. 1 (96), 113-120. GOODS doi:10.37734/2518-7171-2020-1-14

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 the 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.

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 oil flax 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 national economy needs deep transformations, particularly in light industry. In Ukraine, domestic producers continue to gradually lose many segments of the domestic market of goods, which is associated with the low competitiveness of domestic enterprises in the conditions of economic openness and accession to the WTO.

In our country, 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 currently operating. There is no general industry information and analytical center for light industry, and no one carries out detailed statistical accounting of production volumes and other economic indicators of the work of enterprises.

However, the light industry of Ukraine is an industry with a powerful production potential, capable of producing a wide range of consumer products, including technical products. In our opinion, in order to successfully compete at the domestic, European and global levels, it is necessary to apply a new approach to production using innovative technologies for obtaining technical textiles of various functional purposes based on our own cheap environmentally friendly raw materials – oil flax fiber.

Thanks to scientific and technological progress, significant changes have occurred in the cultivation of industrial crops in Ukraine in recent years. Sowings of long flax have significantly decreased, and oil flax has increased significantly. For 11 years, it has been ranked 3rd in the list of the most profitable industrial crops after sunflower and rapeseed. This is due to the increasing demand in Europe for seeds of this crop. World production of oil flax seeds also tends to increase every year[42].

The unconditional value of the seeds of this crop is associated with the presence of various organic compounds in it. Flax seeds are an excellent source of balanced essential fatty acids, especially omega-3 acid, which is responsible for the growth and normal state of the body, and also contains such biologically active compounds as sterols, squalene, vitamin E and some other substances. That is why it is widely used in many countries.

The main consumer of the seeds of this crop, from which flax oil and meal are obtained, in Ukraine is the processing industry. Flax oil is also a raw material for technical purposes in the chemical industry. Flax meal is an excellent component with a high protein content for the production of compound feed. However, the chemical industry and livestock farming in Ukraine are currently in decline, so flax is processed only by individual private companies. Flax meal is actively used as feed for the private sector only in the regions where the seeds of this crop are grown and processed.

Since 2008, when GM additives were found in Canadian flaxseed, the EU has shown great interest in seeds from the CIS countries, as they are environmentally safe. Thus, the total volume of exports of this product from Kazakhstan and Ukraine as of the end of July 2012 was 510 thousand tons, which is 2 times more than the indicators of the previous year (237 thousand tons). The main buyers of Ukrainian oilseed flax were Belgium – 8659 tons, Poland – 4286 tons, Lithuania – 2945 tons, Germany – 2048 tons, Italy – 1542 tons. In 2012, an unexpected importer of Ukrainian flax appeared – Vietnam, which purchased almost 10 thousand tons of seeds. In total,

[42] Horach O.O., Tikhosova G.A., Zabrodina O.S. (2021) Problems of forming composite materials reinforced with bast fibers Tovaroznavchy visnyk: collection of scientific papers. Issue 14. Lutsk: RVV Lutsk National Technical University. P. 267-274. https://doi.org/10.36910/6775-2310-5283-2021-14

Ukraine exported 30 thousand tons of flaxseed, or almost 5.9% of the above-mentioned total exports[43].

The increase in global demand for Ukrainian flaxseed contributes to the constant growth of the sown areas allocated for this crop.

Despite the fact that flaxseed export is a promising direction due to its growing popularity on the world market, so far flax straw in Ukraine is almost not used in industrial production. However, there are potential consumers of this raw material in our country.

According to statistical data from state institutions, in 2015, Ukraine had 58 firms and companies producing technical textiles, more than 100 pulp and paper enterprises and 2,424 small and large light industry enterprises producing household textiles.

Thus, today in Ukraine there are successfully operating enterprises engaged in the manufacture of a wide range of technical products. Thus, the company "VELAM" produces high-quality environmentally friendly products, using modern technologies and European quality standards in production. Currently, the company is represented by about 500 enterprises in our country. The successful development of the company indicates that technical products are in great demand both in the domestic and foreign markets[44].

The list of products currently manufactured is represented by the following technical products: mattresses, sleeping bags, non-woven materials, as well as upholstered furniture. Non-woven materials are widely used for the production of mattresses by the VELAM company. They are diverse in purpose, properties, structure and physical and mechanical characteristics.

The most actively used materials are Sprut, Thermoflex, Thermofelt and Velaflex (Fig. 15-18). Some of them act as a frame, thanks to which a stable shape of mattresses is formed and the load is distributed. Bulky but dense materials in combination with other floorings (latex, coir) form an obligatory soft element of mattresses. Quilted covers contain light bulk fillers, including those containing siliconized polyester fibers.

All non-woven materials used are products of the VELAM company. The main component of the raw materials is various polyester fibers.

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43 Mezrea, P.E., Ispir, M., Balci, I.A., et al. (2021). Diagonal tensile tests on historical brick masonry wallets strengthened with fabric reinforced cementitious mortar. Structures, eISSN 2352-0124, Vol. 33, 935-946, https://doi.org/10.1016/j.istruc.2021.04.076

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

To simulate the properties of these materials, natural fibers are introduced into their composition: cotton, linen, hemp, wool, coconut fibers, including regenerated fibers.

Fig. 15. Bulk nonwoven material "Sprut"

Source: Velam. www.velam.com.ua/ua/catalogue/netman/nikotex

The bulk nonwoven material "Sprut" is no longer a novelty on the Ukrainian materials market. Its production was first started in the post-Soviet space in Mykolaiv in 1998. After long tests, changes and improvements to its production technology, its use as a flooring material in furniture based on spring blocks was recognized as the most optimal. The material allowed finding new solutions in the technology of mattress production.

"Sprut" is a bulk nonwoven fibrous flooring material. It is distinguished by its ability to increase the effect of elasticity and durability of mattress surfaces. The author's (company "VELAM") technologies of combining PET fibers with cotton, wool and hemp fibers in optimal ratios ensure high quality materials for mattresses: maximum degree of air permeability, heat generation and heat exchange. The material is environmentally safe, exposed to high temperature.

"Thermoflex" material from the company "VELAM" is an analogue of the "Sprut" material. For its production, a similar raw material is used – a mixture of polyester fibers and regenerated cotton and wool fibers, however, due to the change in technology, the orientation of the fibers in the structure of the material has also changed from vertical to horizontal. As a result, the non-woven material "Thermoflex" differs in properties from the material "Sprut": it is more elastic and wear-resistant; both of these materials have high air permeability. The elastic volumetric structure of the material "Thermoflex" from compacted horizontal layers of fibers combines stability and elasticity of the surface, increases the height of the mattress and at the same time evenly distributes the load.

Fig. 16. Thermoflex nonwoven material

Source: Velam. www.velam.com.ua/ua/catalogue/netman/nikotex

"Thermofelt" is a flooring material from the company "VELAM", a product of thermal bonding of fibers and an integral element of a quality mattress. It is designed to distribute the load and create stable protection of soft flooring from the metal structure of the spring block.

Fig. 17. Non-woven material "Thermofelt"

Source: Velam. www.velam.com.ua/ua/catalogue/netman/nikotex

Selection of the optimal fiber composition and material density allows you to simulate certain properties of different mattress models, leveling or enhancing the level of their rigidity and elasticity.

The material is produced in the form of plates and in the form of rolls of 10-50 m, depending on the density of the material.

Areas of application: furniture industry – hard flooring during the production of mattresses, forming upholstered furniture; automotive industry – for reinforcing parts, as a sound-absorbing insulation.

"Velaflex" is a volumetric material from a combination of PET fibers, which have increased biostability. It is characterized by antistatic and hypoallergenic properties. Due to these properties, "Velaflex" improves not only the quality of mattresses, but also the quality of a person's rest environment.

Advantages of the material: absence of adhesive components, high elasticity and breathability, that is, the presence of higher-level properties that determine its quality, comfort and durability. Additional advantages of mattresses using Velaflex are increased elasticity of mattress surfaces, creation of conditions for active air exchange inside the products, and therefore, improvement of the ecology of the recreation area.

Fig. 18. Non-woven material "Velaflex"

Source: Velam. www.velam.com.ua/ua/catalogue/netman/nikotex

Based on the analysis of nonwovens currently used to manufacture products of the company "VELAM", it can be concluded that the main component of the raw materials for their production are various polyester fibers. And only for modeling the properties of materials is used a small amount of natural fibers, which are mainly represented by coconut fiber and regenerated natural fibers.

Analysis of the results of experimental studies of the quality indicators of oil flax fiber, which were carried out in recent years, conducted by scientists of the Kherson National Technical University, allows us to conclude that the production of environmentally friendly technical textiles of various functional purposes using oil flax fiber is an urgent task for Ukraine in the conditions of a market economy. Successful introduction into production at domestic enterprises of annually renewable oil flax fiber will contribute to the production of high-quality competitive products of technical purpose in our country[45].

The cost of coconut fiber, which is currently used for the production of non-woven materials by the company "VELAM", is 38,000 UAH/t. The price of domestic annually renewable oil flax fiber is 18,000 UAH/t, that is, it is half the cost of coconut fiber. In addition, this fiber does not require customs clearance and transport costs for delivery, since it does not need to be imported into the territory of Ukraine.

The use of oil flax fiber 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, fiber and coir – will improve the environmental situation in Ukraine, reduce the fire hazard situation in the south of Ukraine, where oil flax 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 global textile market. However, in order for the resulting products to compete with imported products, it is necessary to carry out scientific research and introduce innovative technologies for the use of flax oilseed fiber for the manufacture of technical products[46]

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 oil flax, which until recently was considered a poorly suited or even unsuitable raw material, since the stems of this crop contain mostly short fibers. Until a certain time, oil flax fiber was not used effectively

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45 Horach, O.O., Tikhosova, G.A., Zabrodina, O.S. (2021). Problems of forming composite materials reinforced with bast fibers Tovaroznavchy visnyk: collection of scientific papers. Issue 14. Lutsk: RVV Lutsk National Technical University, 267-274. https://doi.org/10.36910/6775-2310-5283-2021-14

46 Khan, S.U.; Labonne, L.; Ouagne, P.; Evon, P. (2021). Continuous mechanical extraction of fibres from linseed flax straw for subsequent geotextile applications. Coatings. 11, 852. [CrossRef] https://doi.org/10.3390/coatings11070852

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 currently used in the EU countries are used, the fiber of this crop can be used for the production of technical textiles: nonwovens, insulation, geotextiles and agrotextiles. Therefore, oil flax fibers are a worthy alternative to cotton, which is imported into our country on order of domestic textile manufacturers. The use of our own cheap annually renewable raw materials in the domestic textile industry will contribute to solving the problem of import substitution and will allow filling the Ukrainian market with environmentally friendly and safe products for technical purposes[47].

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.

Introduction into production of innovative technologies for obtaining technical textiles of various functional purposes using oil flax fiber is an important task of today, which will ensure the expansion of the scope of its application in industry. Since flaxseed is an environmentally friendly raw material, it will allow for import substitution of cotton in the production of cellulose, geotextiles, composite and nonwoven materials, sanitary and hygienic products, etc. A promising area of application of flaxseed is also the production of composite materials. Fifty years ago, composite materials were not so widely used, and only a narrow circle of specialists knew about the modern concept of "composites". However, the rapid development of science and technology leads to the creation of new materials on the existing raw material base, but using new component formulations and manufacturing technologies. This provides the possibility of obtaining materials that have high operational properties, are characterized by durability and reliabil-

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[47] Hägglund, M. (2020). Rebuilding Sweden's crisis preparedness : Lack of clarity impedes implementation. FIIA. Finnish Institute of International Affairs, ISSN 1795-8059, Vol. 5, https://www.fiia.fi/wp-content/uploads/2020/05/bp283_sweden_crisis-preparedness.pdf

ity[48]. Many composites surpass traditional materials and alloys in their mechanical properties; they are characterized by high strength, rigidity, and at the same time they are lighter. The use of composites usually allows you to reduce the mass of the structure while maintaining or improving its mechanical characteristics.

According to the structure of the filler, composite materials are divided into:

– fibrous – reinforced with fibers and filamentary crystals;
– layered – reinforced with films, plates, layered fillers;
– dispersion-reinforced – with fillers in the form of finely dispersed particles.

Fig. 19 shows a diagram of the structure of composite materials.

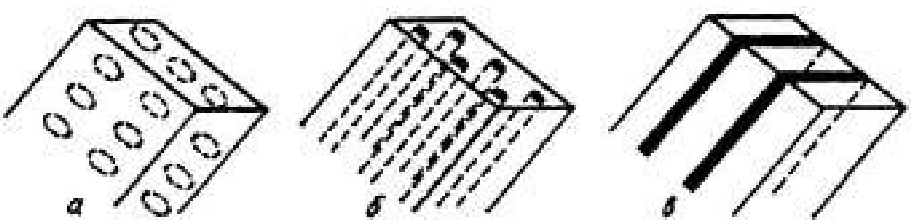

Fig. 19. Structural scheme of composite materials:
a – dispersion-reinforced; b – fibrous; c – layered

Source: Composite materials.
https://stud.com.ua/36297/tovaroznavstvo/kompozitsiyni_materiali

The choice of reinforcing fiber is determined primarily by the requirements for the quality of the final product. The main materials from which reinforcing fibers are made (both short and long) are glass, graphite, aluminum, carbon, boron and beryllium. Natural fibers such as flax, hemp, jute, sisal, coconut, etc. are also used for reinforcement.

Currently, Finland and Germany produce structural materials reinforced with flax fiber. North America has also begun to use composites made of natural fibers.

[48] Ahrari, M., Karahan, M., Karahan, N. (2023). Competitiveness Factors in Textiles and Composites Industry and Transformation into Value-Added Products. RECENT journal, Vol. 24, is. 2(73), pp. 132-141, https://doi.org/10.31926/RECENT.2023.70.132

Composite materials reinforced with plant fibers are most widely used in the automotive industry. Today, strong, corrosion-resistant, lightweight polymer composites are increasingly used for the production of cars. In modern cars, they make up more than 10% (by weight) and their content is constantly increasing[49].

Reinforcing plastics with natural fibers, such as flax fiber, allows you to significantly simplify, compared to fiberglass reinforcement, the processing of parts that have served their time. Thus, the fiber of this crop, having the appropriate physical and mechanical characteristics, can be widely used in the automotive industry for the production of composite materials. Therefore, the development of domestic resource-saving technologies for processing flax straw stalks in order to obtain cellulose-containing semi-finished products suitable for reinforcing composite materials is an urgent task today.

Flax fiber filler can be used to reinforce structural polymer materials both in the form of a pre-formed non-woven material and in the form of a mixture with a heated polymer. It is obtained in the processes of casting, extrusion or pressing. The interaction of fibers with the matrix should ensure high realization of the mechanical properties of the fibers in the reinforced material and its monolith city. This requires: high wettability of the fibers by the matrix; high adhesion between the fiber and the matrix, which is characterized by shear strength at the fiber-matrix interface; absence or minimal change in the properties of the fibers under the action of the matrix components; relaxation of internal stresses in the elementary volume of the fiber-matrix during heat treatment or under the action of the binder components and other factors[50].

The selection of components of composite fibrous materials is carried out taking into account the individual properties of the fibrous semi-finished product and the polymer matrix, as well as their mutual influence, which is determined by many factors, the main of which are: strength, deformation and other properties of the fibers, heat resistance, length and diameter of the

49 Ari A., Karahan M., Karahan N. (2024). Competency Mapping of Textile and Composite Industries: A Regional-Global Case Study. RECENT, eISSN 2065-4529, Vol. 25, is. 1(72), 20-39, https://doi.org/ 10.31926/RECENT.2024.72.020

50 Karahan, M., Ahrari, M., Karahan, N. (2023). Composite Materials Market Research and Export Potential Analysis:A Regio-Global Case Study. RECENT journal, Vol. 24, is. 2(73), 113-121, https://doi.org/ 10.31926/RECENT.2023.70.113

fibers, structure of the fibrous material, viscosity of the polymer matrix under processing conditions.

Reinforcing fibrous semi-finished products are intermediate materials containing a given amount of fibrous filler and polymer matrix, prepared for direct use. They are a convenient release form of semi-finished products prepared for the production of composite materials and products. Most often they are produced in granular form, but can also be in the form of threads, bundles, tapes, fabrics, non-woven fabrics and paper.

It should be noted that reinforcing fibrous semi-finished products made on the basis of chopped fibers containing a given amount of starting components – thermosetting monomers or oligomers, hardeners and other components – look like fibrous pieces of mass of irregular shape. These can be fibers, tablets, granules, as well as a thick dough-like mass.

The method of reinforcing with natural fibers makes it possible to obtain a diverse range of products that are widely used in mechanical engineering, for the manufacture of building and furniture boards, window frames, etc.

The main advantages of natural fibers are:

– lower specific gravity;
– better heat and sound insulation properties;
– the process of producing natural fibers does not require large labor costs and capital investments;
– depending on the polymer matrix, the fibers can be processed;
– easier disposal.

The length of the fibers is most often in the range from 3 to 20 mm. As binders, phenol-formaldehyde resins are usually used, less often melamine, epoxy and other thermosetting resins. The binder content reaches 40-50% of the mass of the semi-finished product[51].

Reinforced fiber semi-finished products are obtained by combining fiber fillers with a polymer matrix. As a result of research by scientists from different countries of the world, it has been found that sometimes it is necessary to modify the surface of the fibers or the composition of the polymer

[51] Karahan, M., Ari, A., Karahan, N. (2024). Examination of R&D Capacity in the Technical Textile Sector: A Regio-Global Case Study. RECENT, eISSN 2065-4529, Vol. 25, is. 1(72), 4-19, https://doi.org/10.31926/RECENT.2024.72.004

matrix to improve wettability and adhesion[52]. For this purpose, various methods are used: chemical modifying treatments of fibers, etching with oxidizing agents, surface hydrolysis, etc. Thus, it can be stated that a very important characteristic of reinforced fibrous semi-finished products is the achievement of high quality impregnation and the absence of air inclusions both at the fiber-binder interface and in the binder layer. Only under these conditions can the production of high-quality monolithic fibrous composites be ensured.

In addition, an equally important problem is ensuring a long shelf life of reinforced fiber semi-finished products without losing their technological properties. This is mainly due to the choice of binders, the curing rate of which is quite low under the conditions of storage of reinforced fiber semi-finished products. The properties of composite materials obtained from reinforced fiber semi-finished products are determined by their physico-chemical characteristics.

The leading manufacturer of composite materials, including those reinforced with natural fibers, in Ukraine is the subsidiary enterprise "Plastmas" of the limited liability company "Trading House Plastmas – Pryluky" (hereinafter the leading manufacturer of these products in Ukraine is the enterprise of the State Enterprise "Plastmas" LLC "TD Plastmas-Pryluky"). It 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 raw material for the production of insulation of protective sheaths of wires and cables;
- phenolic molding compounds (phenolic compounds), which are the raw material for the production of reinforced and unreinforced products for technical purposes;
- 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.

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52 Horach, O.O., Tikhosova, G.A., Zabrodina, O.S. (2021). Problems of forming composite materials reinforced with bast fibers Tovaroznavchy visnyk: collection of scientific papers. Issue 14. Lutsk: RVV Lutsk National Technical University, 267-274. https://doi.org/10.36910/6775-2310-5283-2021-14

The enterprise operates stably, monthly increasing the production volumes of products that are consumed not only in Ukraine, but also exported to the CIS countries. SE "Plastmas" LLC "TD Plastmas-Pryluky" has an ISO 9001:2000 certificate for the quality management system.

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 State Enterprise "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.

Thus, the State Enterprise "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) and others. are successfully conducting 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[53].

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.

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

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.

2.5. Use of oil flax seeds in the food industry

In the history of Slavic peoples, flax has been of great importance since ancient times as a technical crop in weaving and as a medicinal agent in folk medicine. Today, flax seeds produced by ZAO "Liktravy" are a recognized medicinal product, and flax seed oil is a valuable dietary supplement to the diet. It contains valuable PUFAs necessary for all vital processes of the body. At the same time, flax seed oil is ahead of other vegetable oils in terms of the content of omega-3 PUFAs. These acids help strengthen immunity, help in the fight against inflammatory, cardiovascular and endocrine diseases, and help remove harmful substances from the body. And lignans (plant hormones) contained in flax seed oil are well-known antioxidants that prevent the development of malignant tumors. Vitamins A, B, E, F regulate lipid and cholesterol metabolism, enrich the body with vitamins of youth (A, E). Of course, what oil is without trace elements? Yes, flax seeds and products made from them are an important source of selenium, an element important in the prevention of cancer[54].

Recent studies have revealed the extraordinary medicinal properties of flaxseed oil. Unsaturated fatty acids accelerate the metabolism of cholesterol in the blood and promote its excretion, improve metabolism, have a positive effect on blood pressure, reduce the risk of cardiovascular and cancer diseases, and allergic reactions. Preparations made on the basis of flaxseed oil successfully treat burns and skin inflammation. In turn, flaxseed processing products, namely cake and meal, are very valuable feed for livestock.

The domestic market is characterized by a balance between supply and demand for oil flaxseed. This is influenced by the fact that not all oil and fat processing plants are engaged in the processing of flaxseed. In order to process such seeds, it is necessary to form appropriate reserves of raw materials

[54] Horach, O.O., Dombrovska, O.P., Chursina, L.A. (2021). Innovative directions of using oilseed flax and ecological safety of food products. Collective monograph "Formation of a new paradigm of the development of the agro-industrial sector in the 21st century". Vol. 2. Kherson, 593-619. doi:10.30890/2709-2313.2023-23-01

to ensure the continuous operation of technological lines and the production of oil in a sufficient volume to form a commodity batch. It should be borne in mind that some processing enterprises temporarily or completely refuse to process oil flax in the middle of the season. In addition, the processing plant in the city of Donetsk, which specialized in such seeds, suspended its activities due to military operations in the region.

Flaxseed is an export crop. Its internal processing is insignificant. More than 30 thousand tons of this seed are exported annually. The main buyers of Ukrainian flax are Belgium, Poland, Lithuania, Germany, and Italy. The main products of processing are linseed oil, cake, and meal. In turn, flaxseed cake is used by the private sector only in the regions where the product is produced[55].

The supply of oilseed to processing enterprises has its own specifics. The greatest trading activity on the market was observed in August-September, in the period after the harvest of the crop. It is at this time that the main commercial volumes of products are sold. In the middle of the season, commercial seeds enter the market in limited quantities. For the most part, these are batches of up to 10 tons, which are of little interest to buyers. Export-oriented companies are ready to purchase oilseeds at the highest existing prices, but the market has formed a shortage of large-tonnage batches of the appropriate quality of this seed.

The sale of the grown crop is carried out from the producers' own warehouses. Ukrainian elevators do not accept oilseeds for storage due to the small volumes and the need for significant seed processing. Batches of this product must meet the following requirements: moisture content of up to 9%, waste impurities of 2%, oil impurities of 4%, oil content of at least 35%, and be free from pests, which can be achieved through additional cleaning and drying. In addition, sending the product for export requires its packaging in bags or big bags, and most elevators do not have the necessary equipment for this[56].

55 Ahmad, A., Zulfiqar, S., & Chatha, Z. A. (2020). Development of roasted flax seed cookies and characterization for chemical and organoleptic parameters, Pakistan Journal of Agricultural Sciences, 57, 229-235. https://doi.org/10.21162/PAKJAS/20.6552

56 Ahmad, N., Manzoor, M. F., Shabbir, U., Ahmed, S., Ismail, T., Saeed, F., Nisa, M., Anjum, F. M., & Hussain, S. (2020). Health lipid indices and physicochemical properties of dual fortified yogurt with extruded flaxseed omega fatty acids and fibers for hypercholesterolemic subjects. Food Science & Nutrition, 8(1), 273-280. https://doi.org/10.1002/fsn3.1302

Flaxseed oil is a source of nutrients and can be used as a food product. The benefits of natural flaxseed oil have been known since ancient times. So, in the 19th century, it was the main source of vegetable fats in the diet of the population. The unique composition of flaxseed oil is so valuable for the human body that it can be the most important among other edible vegetable oils[57]. Flaxseed oil is a source of polyunsaturated fatty acids: linolenic, linoleic, oleic, which are better known as acids under the general name "Omega". The human body does not produce these acids and can only obtain them from the outside. The composition of linseed oil is so rich in useful substances that it is enough to eat 1-2 tablespoons of it to meet the daily need of the body in fatty acids and fats of vegetable origin.

Flaxseed oil (Fig. 20) is gaining popularity among the population of Ukraine. Despite the fact that it is more expensive than sunflower and has a specific taste, the demand for it remains stable due to the presence of a huge amount of useful substances in its composition. That is why many manufacturers of vegetable oils, seeking to expand their range, choose linseed oil.

Fig. 20. Flaxseed oil and seeds

Source: Flax seeds. Useful properties, use for weight loss and is there any harm. https://belok.ua/blog/ua/semena-lna-polza-i-primenenie/

[57] Ahmadniay motlagh, H., Aalipanah, E., Mazidi, M., & Faghih, S. (2021). Effect of flaxseed consumption on central obesity, serum lipids, and adiponectin level in overweight or obese women: A randomised controlled clinical trial. International Journal of Clinical Practice, 75(10), e14592. https://doi.org/10.1111/ijcp.14592

Linseed oil is used in cooking, perfumery, and medicine. Recent studies have revealed extraordinary therapeutic and prophylactic properties of linseed oil, thanks to which its use helps to reduce blood cholesterol levels and its excretion, improves protein and fat metabolism, has a beneficial effect on blood pressure, relieves spasms of blood vessels, and prevents the formation of blood clots and tumors. Biological compounds such as lignins cause the blocking of enzymes involved in hormonal metabolism, inhibit the growth and spread of cancer cells. Preparations made from linseed oil are used externally for radiation skin lesions and burns. Linseed oil is the best helper for the immune system[58].

The composition of flaxseed oil includes such fatty acids as: palmitic (5-7%), stearic (3-4%), oleic (16-20%), linoleic (14-17%), linolenic (50-60%). Flaxseed oil can be divided into four categories according to its linolenic acid content: linolenic acid content of more than 50% – high, the oil is suitable mainly for technical purposes; linolenic acid content of 36-49% – medium, the oil is suitable for technical purposes, in medicine, perfumery; linolenic acid content of 10-35% – low, the oil is suitable mainly for food purposes; linolenic acid content of less than 10% – very low, the oil is suitable only for food purposes[59].

It should be noted that all flaxseed oil can be consumed, but the high content of linolenic acid in the oil leads to its rapid oxidation and rancidity, shortens the shelf life of food to two months and thus limits the widespread introduction of flaxseed oil into the pharmaceutical and food markets, and reduces its commercial value in industrial production.

The problem of long-term storage of flaxseed oil in the world is solved by breeding special varieties with a reduced content of linolenic and increased oleic acids. The most suitable for food purposes are varieties of medical and food flax with increased oxystability due to the changed qualitative composition of the oil and the content of antioxidants (tocopherols, flavonoids, etc.), which significantly extends the shelf life of the oil.

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[58] Horach, O.O., Dombrovska, O.P., Chursina, L.A. (2021). Innovative directions of using oilseed flax and ecological safety of food products. Formation of a new paradigm of the development of the agro-industrial sector in the 21st century" edited by Avercheva O.V. Collective monograph. Kherson: Liga-Press, Volume 2, 593-619. https://doi.org/10.30890/2709-2313.2023-23-01-014

[59] Akter, Y., Junaid, M., Afrose, S. S., Nahrin, A., Alam, M. S., Sharmin, T., Akter, R., & Hosen, S. Z. (2021). A comprehensive review on Linum usitatissimum medicinal plant: Its phytochemistry, pharmacology and ethnomedicinal uses. Mini Reviews in Medicinal Chemistry, 21(18), 28012834. https://doi.org/10.2174/1389557521666210203153436

Currently, consumers are increasingly turning to flaxseed because of its beneficial effects on human health. Studies have shown that consuming flax seeds improves digestion, stimulates the activity of the gastrointestinal tract and helps regulate blood glucose levels. Flax seeds have also been widely used since ancient times as a medical remedy for preparing decoctions. Flax seeds contain 100 times more biologically active substances – lignans – than other plants. They have a positive effect on the body's immune system, reduce the risk of cancer and diabetes[60].

The nutritional value of flaxseed protein in a point estimate (casein, taken as 100) is estimated at 92 units. It does not lose its properties for three years and is widely used in countries around the world as an additive to various types of bread, sprinkling confectionery. The foreign baking industry widely uses flaxseed as a component for baking baked goods. In addition to usefulness, pastries acquire a tenderness of taste caused by the fat component and a characteristic crunchiness. In Germany, more than 60 thousand tons of flaxseed are used annually in baking and for preparing various dishes. On average, this is about 1 kg per person per year, or 2.5 g per day. Flaxseed can be used in yogurts, grain dishes and salads. The Ministry of Health of Canada and the USA recommends the mandatory daily consumption of flaxseed in food. In Canada, flaxseed is even considered a separate type of food product, rather than a food supplement. In supermarkets in North and South America, as well as in Europe and Asia, you can buy chicken eggs enriched with flaxseed nutrients[61]. Fig. 21 shows a sample of the range of flaxseed oil that can be purchased as a dietary supplement at a pharmacy.

Fig. 21. Flaxseed oil producer LYKTRAVY (Ukraine)

Source: Flaxseed. https://liktravy.ua/lonu-nasinnja-dd-200-g-p22055502800000

[60] Bennato, F., Ianni, A., Innosa, D., Grotta, L., D'Onofrio, A., & Martino, G. (2020). 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, 33(1), 148-156. https://doi.org/10.5713/ajas.18.0868

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

In the range of varieties of oil flax, included in the State Register of Plants of Ukraine, the mass of 1000 seeds varies within 7-8 g. A feature of food varieties is lower than that of technical varieties, the mass of 1000 seeds (within 5-6 g). Such seeds meet the requirements of the confectionery industry on the world market.

Edible oil, which is used in the food, pharmaceutical and cosmetic industries, is obtained only by cold pressing (at temperatures below 35°C). The main advantage of such technology is that it does not require the use of chemical solvents and allows you to produce a natural product with the preservation of all useful substances in their natural state.

A mandatory requirement for the production of edible oil is high-quality raw materials. The quality of raw materials that are sent for processing is characterized by moisture and dirtiness. Selected, fresh dried seeds with a moisture content of no more than 10% are used. In terms of contamination, flaxseed with a content of up to 1% of impurities is considered clean. The use of stale, old seeds leads to a deterioration in the quality of the final product – the oil will be rancid, and the shelf life will be noticeably reduced.

Edible oil has its own characteristics: color – light yellow of various shades, transparent after settling, without foreign odor, taste, bitterness. Acid number – no more than 2.0 (oil with an acid number of 2.2 and above is considered technical). Specific gravity – 0.928-0.942. Refraction – 68-79. Iodine number – 157-205. Saponification number – 184-194. Unsaponifiable matter – no more than 1%. Flaxseed oil should only be used cold. During the processing of edible flax seeds into linseed oil, another by-product is formed – cake, which can be used as a protein additive for organic feed[62].

The oilcake processing technology improved at the Institute of Oil Crops by introducing an additional operation of mechanical fractionation of crushed oilcake into protein and husk fractions allows to isolate more than 40% of protein powder with a protein content of at least 38%. The husk fraction, which includes the bulk of fiber, is used to produce fuel briquettes.

The content of 8-12% of oil in protein powder contributes to its rapid oxidation, which leads to a decrease in the quality of the protein supplement. To increase the time of the oxidation process, it is proposed to produce the protein fraction in the form of pellets. In addition to avoiding rapid oxida-

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

tion, the pelleting process will reduce the volume of product storage in warehouses and reduce the costs of their transportation. Therefore, solving the issues of mechanization of oilcake processing by improving the technology and equipment for separating it into protein fraction (pellets) and husk (fuel briquettes) is quite relevant[63].

The Institute of Oilseeds of the NAAS has proposed a line for processing edible flax seeds, which includes the following stages of the technological process. Unfiltered oil and cake are obtained from commercial oilseeds using a press. Unfiltered oil passes through a filtration line, as a result of which purified oil is released, which is used for food purposes, and fuzz, which is used as a highly nutritious feed additive. The cake is crushed and divided into two fractions: protein and husk. The husk fraction is used as one of the components for the manufacture of fuel briquettes, and the protein fraction can be used as a component for obtaining dry feed pellets. Also, the protein fraction, together with fuzz, feed grain, grain waste and premixes, are processed into liquid feed using a cavitation disperser[64].

Recently, the consumption of flax seeds and flax oil has become very popular. The healing properties of flax seeds are due to its lignans, which have a wide range of biological activity, including antibacterial, antiviral and antifungal effects. Polyunsaturated fatty acids and soluble fiber have anticancer properties and have been called the elixir of life. In this regard, flax should be used not only as a raw material for the production of oil and fat products, but also for the production of a wide range of products, in particular bakery, cereal, confectionery, culinary and food additives based on flax products. Therefore, the main task of domestic breeders is to create new varieties of flax that meet the requirements of the food industry, taking into account the need to preserve the functional properties of flax during storage and processing into food products[65].

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[63] Gorach, O. (2023). Current state of production and prospects of the use of oily flax seed in the food industry / Intellectual and technological potential of the XXI century: Innovative technology, Computer science, cybernetics and automation, Architecture and construction, Chemistry and pharmaceuticals. Monographic series «European Science». Book 23. Part 1, 41-59. https://doi.org/10.30890/2709-2313.2023-23-01-014

[64] Offer – The main magazine on agribusiness https://propozitsiya.com/ua/harchoviy-napryam-vikoristannya-lonu-oliynogo

[65] Drozłowska, E., Łopusiewicz, Ł., Mężyńska, M., & Bartkowiak, A. (2020). The effect of native and denaturated flaxseed meal extract on physiochemical properties of low fat mayonnaises. Journal of Food Measurement and Characterization, 14(2), 1135-1145. https://doi.org/10.1007/s11694-019-00363-6

The composition of flaxseed determines its value as a dietary product, which is widely used in the food industry today. Flaxseed is rich in proteins, fats, gluten and fiber. The composition of flaxseed of Canadian varieties, which dominate the world production of flax, in terms of dry matter is as follows: fat component – 41%, proteins – 21%, fiber – 28%, aromatic acids, lignin and hemicellulose, sugars – 6%, ash residue – 4%[66].

Fig. 22. Flaxseed oil

Source: Flax seeds: healing properties and benefits for the body.
https://ptv.ua/news/d6ee5f04-e1a4-4c37-8825-42aeb7d7a89a

The composition of flaxseed varies significantly depending on the variety, growing environment, and flax processing methods[67,68].

The content of nutrients, namely calories, proteins, fats, carbohydrates, vitamins and minerals per 100 g of edible part is given in Table 9-13.

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66 Duman, M. (2020). Nutritional value and sensory acceptability of fish burger prepared with flaxseed flour. Food Science and Technology (Campinas), 42, e27920. https://doi.org/10.1590/fst.27920

67 Ghafouri-Oskuei, H., Javadi, A., Asl, M. R. S., Azadmard-Damirchi, S., & Armin, M. (2020). Quality properties of sausage incorporated with flaxseed and tomato powders. Meat science, 161, 107957. https://doi.org/10.1016/j.meatsci.2019.107957

68 Gorach, O. (2023). Current state of production and prospects of the use of oily flax seed in the food industry. Intellectual and technological potential of the XXI century: Innovative technology, Computer science, cybernetics and automation, Architecture and construction, Chemistry and pharmaceuticals. Monographic series «European Science». Book 23. Part 1, 41-59. https://doi.org/10.30890/2709-2313.2023-23-01-014

Table 9. Vitamin content in flax seeds

Name	Number
Lutein + Zeaxanthin	651 мкг
Vitamin B1, thiamine	1.644 мг
Vitamin B2, riboflavin	0.161 мг
Vitamin B4, choline	78.7 мг
Vitamin B5	0.985 мг
Vitamin B6, pyridoxine	0.473 мг
Vitamin B9	87 мкг
Vitamin C, ascorbic acid	0.6 мг
Vitamin E, alpha tocopherol, TE	0.31 мг
gamma tocopherol	19.95 мг
delta tocopherol	0.35 мг
Vitamin K, phylloquinone	4.3 мкг
Vitamin PP, NE	3.08 мг
Betaine	3.1 мг

Source: Ways to increase the nutritional and biological value of bakery products https://surl.li/rhhvzg

Table 10. Nutritional value of flax seeds per 100 g

Name	Number
Calories	534 ккал
Protein	18.3 г
Fat	42.2 г

Name	Number
Carbohydrates	1.6 г
Carbohydrates (total)	28.9 г
Dietary fiber	27.3 г
Water	7 г
Ash	3.7 г

Source: Ways to increase the nutritional and biological value of bakery products https://surl.li/rhhvzg

Table 11. Amino acid composition of flaxseed

Name	Number
Essential Amino Acids	
Arginine*	1.925 г
Valine	1.072 г
Cytidine*	0.472 г
Isoleucine	0.896 г
Leucine	1.235 г
Lysine	0.862 г
Methionine	0.37 г
Threonine	0.766 г
Tryptophan	0.297 г
Phenylalanine	0.957 г
Essential amino acids	
Alanine	0.925 г

Name	Number
Aspartic acid	2.046 г
Hydroxyproline	0.175 г
Glycine	1.248 г
Glutamic acid	4.039 г
Proline	0.806 г
Serine	0.97 г
Tyrosine	0.493 г
Cysteine	0.34 г

Source: Ways to increase the nutritional and biological value of bakery products
https://surl.li/rhhvzg

Table 12. Mineral content in flaxseed

Name	Number
Trace elements	
Potassium, K	813 мг
Calcium, Ca	255 мг
Magnesium, Mg	392 мг
Sodium, Na	30 мг
Sulfur, S	182.9 мг
Phosphorus, P	642 мг
Trace elements	
Iron, Fe	5.73 мг
Manganese, Mn	2.482 мг

Name	Number
Copper, Cu	1220 мкг
Selenium, Se	25.4 мкг
Zinc, Zn	4.34 мг

Source: Ways to increase the nutritional and biological value of bakery products https://surl.li/rhhvzg

Table 13. Fatty acid content in flaxseed

Name	Number
Fatty acids	
Omega-3 fatty acids	22.813 г
Omega-6 fatty acids	5.91 г
Sterols (sterols)	
Campesterol	45 мг
Stigma sterol	11 мг
beta Sito sterol	90 мг
Saturated fatty acids	3.663 г
14:0 Miristinic	0.008 г
15:0 Pentadecanoic	0.005 г
16:0 Palmitic	2.165 г
17:0 Margarine	0.018 г
18:0 Stearic	1.33 г
20:0 Arachidonic	0.052 г
22:0 Behenic	0.052 г

Name	Number
24:0 Lignoceric	0.031 г
Monounsaturated fatty acids	7.527 г
16:1 Palm oleic (ud)	0.024 г
18:1 Oleic (ud)	7.359 г
20:1 Gad oleic (omega-9)	0.067 г
22:1 Erucic (ud)	0.013 г
24:1 Nervonic (omega-9)	0.064 г
Polyunsaturated fatty acids	28.73 г
18:2 Linoleic (ud)	5.903 г
18:3 Linolenic (ud)	22.813 г
20:2 Omega-6	0.007 г

Source: Ways to increase the nutritional and biological value of bakery products https://surl.li/rhhvzg

Analyzing the data in Tables 8-12, we can conclude that flax seeds are rich in such vitamins and minerals as: vitamin B1 – 109.6%, choline – 15.7%, vitamin B5 – 19.7%, vitamin B6 – 23.7%, vitamin B9 – 21.8%, vitamin PP – 15.4%, potassium – 32.5%, calcium – 25.5%, magnesium – 98%, phosphorus – 80.3%, iron – 31.8%, manganese – 124.1%, copper – 122%, selenium – 46.2%, zinc – 36.2%, which indicates its benefits. For example, vitamin B1 is a part of the most important enzymes of carbohydrate and energy metabolism, which provide the body with energy and plastic substances, as well as the metabolism of branched-chain amino acids. The lack of this vitamin leads to serious disorders of the nervous, digestive and cardiovascular systems.

Choline is a part of lecithin, plays a role in the synthesis and metabolism of phospholipids in the liver, is a source of free methyl groups, acts as a lipotropic factor.

Vitamin B5 is involved in protein, fat, carbohydrate metabolism, cholesterol metabolism, the synthesis of a number of hormones, hemoglobin, promotes the absorption of amino acids and sugars in the intestine, supports the function of the adrenal cortex. A lack of pantothenic acid can lead to damage to the skin and mucous membranes.

Flax is distinguished by the yellow color of the seeds, a thin shell and a low content of linolenic acid. Today, the company has developed a grinding technology that maximizes the phytochemical potential of the raw material being processed. This allows for a new grain processing product based on grinding the grain and separating it into separate parts – the seed coat, embryo and endosperm – as a source of substances used to prevent cancer, cardiovascular, gastrointestinal and kidney diseases, diabetes, arthritis and to strengthen the immune system. In addition, new varieties of flax are known, in which the fatty acid composition of edible flax is similar to that of wheat flour, which makes it more suitable for storage[69]. The high fat content in flax flour and bran makes it possible to enrich flour with fatty acids and produce new products with increased nutritional, biological and medicinal properties.

The main advantage of bread made from flax flour or flax bran is its consumer characteristics, i.e. taste and aroma. As an oilseed, flax must meet safety requirements in accordance with established regulatory documents. A balanced and nutritious diet is important for the full development and vital activity of a person. However, with the development of the chemical industry, the nutritional value and quality of many food products not only raises great doubts, but also their usefulness is lost. One of the modern trends in the food industry is the introduction of new waste-free technologies. This involves a more complete extraction of useful components from agricultural raw materials and an increase in the degree of its processing, which makes the issue of developing technologies and recipes for enriched food products relevant. For example, the use of new technologies in the processing of flax seeds would allow the extraction of biologically active compounds, such as sterols, squalene, vitamin E and many other compounds, on the basis of which new domestic groups of biologically active drugs can be created, including medical and health-improving drugs. According to expert esti-

[69] Ghosal, S., & Bhowal, J. (2021). Bioethanol production from enzymatic hydrolyzates of pretreated flaxseed meals by baker's yeast. https://doi.org/10.21203/rs.3.rs-599700/v1

mates, the cost of biologically active substances obtained from flax can reach 80,000 US dollars per ton of processed flax seeds[70].

New technological processes have been introduced in the dairy industry, aimed at the full use of all components of milk and its processing into various food and feed products and semi-finished products. Specialized workshops and sections have been created at the enterprises for the processing of dairy by-products. Equipment and technological lines have also been developed for the processing of skim milk, cheese and whey by traditional and new methods.

Over the past decade, there has been a clear trend towards increasing the production and consumption of low-fat dairy products, for the manufacture of which by-products of dairy production are widely used. Skim milk, cheese and whey are used in the production of various drinks, semi-finished products, desserts, puddings, ice cream and jelly products.

Flaxseed is currently very popular as a food additive. Baking with the addition of flaxseed has a delicate taste due to its high fat content and an attractive crust. Studies have shown that eating bread with the addition of flaxseed for four weeks reduces cholesterol levels by 7-9%.

Flaxseed flour has also been shown to be useful in making gluten-free baked goods. The proteins and gummies of flaxseed are used in products such as ice cream, powdered sauces, and soups. The fatty acid composition of flaxseed oil is unique and contains high levels of polyunsaturated essential fatty acids (PUFAs), which are very important for the healthy functioning of the human body. Western doctors recommend that patients add 1-2 teaspoons of flaxseed oil to their diet to prevent cardiovascular disease and alleviate the progression of diabetes.

Flaxseed oil has been found to improve the adaptation of newborns, promote breastfeeding in women, increase immunity in children with lung diseases, and shorten the duration of treatment for peptic ulcer disease. It has also been proven to improve blood composition by lowering total cholesterol levels[71].

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70 Kairam, N., Kandi, S., & Sharma, M. (2021). Development of functional bread with flaxseed oil and garlic oil hybrid microcapsules. LWT-Food Sci. and Technol., 136, 110300. https://doi.org/10.1016/j.lwt.2020.110300

71 Karwasra, B. L., Kaur, M., Sandhu, K. S., Siroha, A. K., & Gill, B. S. (2021). Formulation and evaluation of a supplementary food (Panjiri) using wheat and flaxseed flour composites: Micronutrients, antioxidants, and heavy metals content. Journal of Food Processing and Preservation, 45(1), e14998. https://doi.org/10.1111/jfpp.14998

Margarine is a well-known edible fat made from a mixture of vegetable and animal fats, milk and other ingredients. Until recently, margarine was made from liquid, refined and deodorized vegetable oils. Sunflower, soybean, cottonseed, sesame and coconut oils were mainly used.

The widespread production of margarine and other soft oils with a reduced content of animal fats was due to the desire to limit the diet of foods containing animal fats, which produce cholesterol. After the health benefits of linseed oil were discovered, the margarine industry, mainly in Canada and the United States, switched to using linseed oil.

After pressing the oil from flax seeds, cake remains. The protein content of this cake increases in proportion to the amount of oil produced, varying between 25% and 54%. Previously, this cake was used only for animal feed. In recent years, the technology for producing flour, protein and other food products from flax seeds has been developing rapidly. Flax seeds can provide up to 70% of the total amount of complete protein in the form of a complex, including more than 20% pure protein. Semi-fat flax flour is now commercially available. Flax flour is used in the production of bakery, confectionery and concentrated products and is suitable for adding protein, dietary fiber and polyunsaturated fatty acids to products[72].

Due to the need to use natural emulsifiers and stabilizers, flaxseed meal is currently used as a natural structure-forming natural ingredient in the production of mayonnaise. The inclusion of flaxseed meal in mayonnaise can affect the mechanisms of formation and stabilization of oil-fat emulsions, change viscosity and increase resistance to thermal oxidation. The structure-forming properties of semi-skimmed flaxseed meal led to the development of dessert products based on whey with a jelly-like lush consistency. Calculations showed that the energy value of the mixture of whey and flaxseed meal was low – 32.45 Kcal per 100 g, and its biological value was significantly higher due to the high content of essential amino acids. It was added to a mixture of flour and whey in a ratio of 1:7, with citric acid and cherry syrup to give the dessert a delicate taste and pleasant color. This product contributes to the full functioning of the gastrointestinal tract and removes toxins, parasites and lipids from the body.

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72 Marand, M. A., Amjadi, S., Marand, M. A., Roufegarinejad, L., & Jafari, S. M. (2020). Fortification of yogurt with flaxseed powder and evaluation of its fatty acid profile, physicochemical, antioxidant, and sensory properties. Powder Technology, 359, 76-84. https://doi.org/10.1016/j.powtec.2019.09.082

The main problem of processing flax seeds to extract the protein component is that the polysaccharides in the seed coat bind to protein molecules during extraction, which makes it difficult to precipitate and purify when obtaining protein. In the case of flax seeds, the outer shell is firmly attached to the kernel and cannot be removed by conventional methods of removing the shell, so flax is processed without separating the shell. In this regard, a technology has been developed that involves pre-cleaning flax seeds using a vibration extractor. This allows you to extract polysaccharides from the seed coat and obtain a new product – flax seed mucus[73]. In connection with the emergence of new by-products of flaxseed processing, a fermented milk product based on skim milk with flaxseed mucus was developed.

Thermophilic streptococci were chosen as starter cultures, which have a positive effect on human microflora, synthesize polysaccharides during fermentation and secrete them into the environment, making the dairy product more concentrated and delaying stratification. With prolonged systematic use, the developed product can reduce the activity of inflammation of the gastric mucosa. The inclusion of medicinal flax mucus can also be used both for the treatment of exacerbations of chronic gastritis and for the prevention of relapses[74].

From the analysis of the nutritional value of flax seeds, we can conclude that flax is a valuable industrial raw material that contains many phytochemical properties that increase the biological value of food products. Therefore, an important task today is to create functional products from natural raw materials that should be safe, affordable, nutritious and beneficial for humans. Thus, oil flax is widely used in the food industry, mainly due to the healing properties of seeds and products of its processing. The number of technologies and recipes using flax oil is increasing every year both in Ukraine and on the world market. Therefore, the need to develop functional preparations makes it relevant to further implement and develop recipes for the production of food products of a wide range of uses[75].

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[73] Sanmartin, C., Taglieri, I., Venturi, F., Macaluso, M., Zinnai, A., Tavarini, S., Botto, A., Serra, A., Conte, G., Flamini, G., & Angelini, L. G. (2020). Flaxseed cake as a tool for the improvement of nutraceutical and sensorial features of sourdough bread. Foods, 9(2), 204. https://doi.org/10.3390/foods9020204

[74] Sapozhnikov, A. N., Kopylova, A. V., Gurova, D. V., & Bolshakov, K. A. (2021). Obtaining of gluten-free pizza dough based on flaxseed flour. IOP Conference Series: Earth and Environmental Science 677(3), 032056. https://doi.org/10.1088/17551315/677/3/032056

[75] Toulabi, T., Yarahmadi, M., Goudarzi, F., Ebrahimzadeh, F., Momenizadeh, A., & Yarahmadi, S. (2021). Effects of flaxseed on blood pressure, body mass index, and to-

In addition, flaxseed is widely used in cosmetics. The unique properties of flax are associated with its chemical composition. Due to the high content of essential oils, omega-polyunsaturated acids and vitamins F, A, B and E, flaxseed actively affects the human body and restores its normal functioning. Saturated organic acids, plant mucus, enzymes and phytoestrogens have an additional strengthening and health-improving effect.

The main products of the European Union are food and feed products made from hemp and flax, that is, seeds obtained from them for the production of medicines. For medical purposes, flaxseed oil is usually made from flaxseed, which is a more concentrated and effective product. The seeds crushed into powder are mixed with warm water, and the proportions may be different (more water for decoctions, less for pastes).

Adding seeds to food is an easy way to increase fiber intake. There are known technologies for adding flaxseed flour in the production of gluten-free baked goods. For example, 20 g of chia seeds contain 6.8 g of fiber, flax seeds – 5.4 g, and pumpkin seeds – 1.3 g. In Ukraine, flaxseed is exported as raw material for sowing and for use in the food and cosmetic industries in Europe[76,77,78].

The main part of exports is raw materials for industrial processing; in 2018-2019, the amount of organic products increased: in 2018, such seeds accounted for 6% of the total volume of supplies; in 2019, it was 14%. However, in Ukraine, studies of the quality indicators of these products have not yet been conducted, and there is no regulatory document that would define them. As a rule, the quality of "superfoods" is assessed according to the technical conditions developed by the manufacturer. Domestic publications do not contain information about national regulatory documents that can be used to assess the quality and consumer characteristics of functional food

tal cholesterol in hypertensive patients: A randomized clinical trial. Explore. https://doi.org/10.1016/j.explore.2021.05.003

76 Gorach, O., Dzyundzya, O., Rezvykh, N. (2024). Innovative Technology for the production of gluten-free food products of a new generation. Current Nutrition & Food Science. № 20 (6), 734-744. https://dx.doi.org/10.2174/0115734013280307231123055025

77 Wirkijowska, A., Zarzycki, P., Sobota, A., Nawrocka, A., Blicharz-Kania, A., & Andrejko, D. (2020). The possibility of using by-products from the flaxseed industry for functional bread production. LWTFood Science and Technology, 118, 108860. https://doi.org/10.1016/j.lwt.2019.108860

78 Horach, O.O. (2022) Justification of innovative technologies of functional formulations. Tavria Scientific Bulletin. Series: Technical Sciences. Kherson State Agrarian and Economic University. Kherson: Publishing House "Helvetica", Issue 6, 52-58. http://journals.ksauniv.ks.ua/index.php/tech/article/view/311/287

products made from flax seeds. Unfortunately, the existing regulatory framework of foreign manufacturers is not available.

2.6. Methods of producing oil from flaxseeds

Mechanical oil pressing from oilseeds is one of the most commonly used methods for extracting oil from oilseeds. This method has relatively low operating costs and, similar to the supercritical CO_2 extraction method, yields uncontaminated oil. However, currently available mechanical oil pressing equipment and processes are not considered the most efficient for this purpose, since the extraction of flaxseeds by pressing allows for the extraction of only 60-70% of the oil. The yield obtained from mechanical pressing is usually lower than that obtained from extraction with solvents such as hexane, for example. Only in the last century has solvent extraction been used in this field. The advantage of solvent extraction technology is the high yield of oil that can be obtained using this method, almost 100% of the oil contained in the oilseed[79].

Two technologies are used in the production of linseed oil: cold or hot pressing and extraction. Depending on the type of processing, it can be unrefined, refined, hydrated and deodorized.

The cold pressing method preserves the maximum beneficial properties of the product, since its composition contains valuable vitamins, phospholipids, unsaturated fatty acids and other biologically active substances.

The ancient method of obtaining oil involved roasting and crushing the seeds in a mortar. Modern technology involves heating the seeds to 35-40 ° C and pressing. Fresh oil is golden or light brown in color with a pleasant sweetish taste and aroma. This is the most useful product, but more expensive than that obtained by any other method: more raw materials are used for its production. Among the disadvantages are a short shelf life and the formation of a natural precipitate.

Unrefined oil can be subjected to further purification: (filtration, hydration, centrifugation, settling), refining (clarification using sorbents), as well as deodorization (neutralization of odor). After such treatment, the oil is obtained clean, transparent, greenish-yellow in color, without a special

[79] Linseed Oil Production Technology [Electronic resource]. Access mode: https://www.bestoilmillplant.com/linseed-oil-production-technology.html

taste and smell. Unfortunately, some of the beneficial substances are lost. Such oil is used for technical purposes.

The raw material is placed in a press extruder, in which it is crushed and heated to 120ºC. In this way, it is possible to achieve a higher yield of the final product, but the effect of high temperature destroys many important components of the oil and reduces its biological value.

This method consists of two stages. First, the raw material is crushed and oil is extracted from it using special solvents. Then the resulting product is driven through a distiller and purified from impurities. This oil loses vitamin E and plant styrenes, but the fatty acid content becomes higher, which worsens its taste and smell, and also reduces its shelf life[80].

When using the extraction method, flaxseed oil contains almost no nutrients, because a lot of chemistry is used to obtain it. At the first stage of extraction, the oil is obtained using solvents, which are subsequently removed by distillers. Oil obtained by hot pressing also loses many of its beneficial properties due to the high temperatures to which the seeds are exposed before extraction. The temperature of the hot press reaches 120 degrees.

The best and most common method of producing flaxseed oil is cold pressing. As the name suggests, here the cleaned and crushed seeds are sent to the press without preliminary heating. About 300 grams of oil is obtained from 1 kg of seeds. Such oil retains its beneficial properties, does not contain traces of synthetic compounds and even retains its specific natural smell.

In recent years, when nutritionists have discovered the medical and biological benefits of flaxseed oil, the margarine industry, primarily in Canada and the USA, has been switching to using flaxseed oil in the manufacture of margarine. Analyzing the above data, it becomes clear why interest in flaxseeds is constantly growing. However, research in this regard is fragmented, there is practically no information on the change in the nutritional value of flaxseeds during storage and processing of semi-finished products[81].

The physical and mechanical properties of flax seeds differ sharply from those of grain and other crops. Flax seed mass is extremely dense, difficult to blow through and "flowing". Many weeds are difficult to separate

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80 Linseed oil: composition, use, benefits [Electronic resource]. Access mode: https://fitomarket.com.ua/ fitoblog/lnjanoe-maslo-sostav-ispolzovanie-polza

81 Farag, M.A.; Elimam, D.M.; Afifi, S.M. (2021). Outgoing and Potential Trends of the Omega-3 Rich Linseed Oil Quality Characteristics and Rancidity Management: A Comprehensive Review for Maximizing Its Food and Nutraceutical Applications. Trends Food Sci. Technol. 114, 292-309. http://dx.doi.org/10.1016/j.tifs.2021.05.041

from the seeds of the main crop. Freshly harvested seeds have a high intensity of metabolic processes, they are unstable in storage, and are characterized by reduced technological properties. Therefore, post-harvest processing of oil flax seeds is more complex. It includes, as in other crops, preliminary cleaning, drying and final cleaning. Flax seeds are cleaned of impurities by blowing with an intense stream of air on sieves with a diameter of 1.7-2.0 mm. Flax seeds are dried in a moving, loosened layer at a temperature of 48-50 ° C, while the temperature of the seeds at the outlet of the dryer should be 38-39 ° C. Heating seeds causes a number of interrelated biochemical processes in them, in particular, a decrease in the acid number of linseed oil as a result of the formation of a protein-lipid complex that binds fatty acids formed during the hydrolysis of fats.

Analysis of literary sources showed that of all the methods of processing flax seeds, the process of obtaining oil is the most well-studied. Also, sufficient attention was paid to the possibilities of using oil production – cake and meal.

Cake is obtained during oil production by pressing, meal – when obtaining oil by extraction. In cake, the amount of crude fat is 5-6%, in meals – 2-3%. Flax cake and meal are excellent protein feed. In order to increase production efficiency and reduce the cost of production, it increases income. Many oil production enterprises are modernizing the classical scheme for obtaining oils. The choice of the method of preparing the material for extraction depends on the composition of the technological scheme, the type of raw material and the extractor equipment[82].

Since the main criterion for product preparation is the creation of favorable conditions for more effective penetration of the solvent into each particle, as well as its distribution between the product particles and the return of dissolved oil to the external solution. With increasing porosity, the specific surface area increases, which is an important parameter that determines permeability – the ability of a porous material to pass liquid through it.

The solvent penetrates more intensively through the pores into the granule, removing oil from capillaries located not only on the surface, but also in the depth of the particle. The interaction of the liquid and the space filled with oil with a fenced or intact cell membrane leads to an increase

[82] Farag, M.A.; Elimam, D.M.; Afifi, S.M. (2021). Outgoing and Potential Trends of the Omega-3 Rich Linseed Oil Quality Characteristics and Rancidity Management: A Comprehensive Review for Maximizing Its Food and Nutraceutical Applications. Trends Food Sci. Technol. 114, 292-309. http://dx.doi.org/10.1016/j.tifs.2021.05.041

in its yield and a decrease in the residual oil content of the meal. Processing of flax seeds to obtain oil is a sequence of a number of technological stages. The gradual removal of oil from flax seeds contributes to an increase in protein in the final product. The technological cycle in this case can be presented as follows: grinding of natural flax seeds – removal of oil by the method of "cold" pressing – grinding of flax cake – removal of residual oil by the method of extraction – grinding of flax meal. At the same time, for the purposes of food production, it is necessary to carry out washing and heat treatment of raw materials, in this case flax seeds. Washing of flax seeds is complicated by the presence of mucus that is well soluble in water and a significant amount of water-soluble proteins.

To create porous pellets of oil cake with certain parameters, a granulation line is introduced into the production chain between grinding and extraction. The shell-shaped oil cake enters the grinding section, where it is ground to a grain size of less than 3 mm and through a cyclone enters an intermediate bunker for storing raw materials. A magnetic separator is installed in front of the granulator, on which the grain is cleaned. Then it is dosed and fed into a continuous mixer, where mixing and steam treatment are carried out to give the product homogeneity and plasticity. Adding steam helps to reduce energy consumption and reduce wear on the working parts of the granulator.

The prepared product enters the granulator. Granulation occurs in the pressing chamber by pushing it through the gears. Hot granules (temperature about 80°C) are cooled by an air flow in the cooler to the temperature required for extraction – 55-60°C. After unloading from the cooler, the cooled granules are separated from small particles on screening and sent to the extraction workshop, and small particles are sent for repeated granulation. For the most complete removal of oil by the extraction method from oil raw materials, traditional solvents are usually used: ethyl alcohol, hexane. Therefore, it is necessary to determine the optimal solvent for removing residual oil from flaxseed cake[83].

[83] Qiu, C.; Wang, H.; Guo, Y.; Long, S.; Wang, Y.; Abbasi, A.M.; Guo, X.; Jarvis, D.I. (2020). Comparison of Fatty Acid Composition, Phytochemical Profile and Antioxidant Activity in Four Flax (Linum usitatissimum L.) Varieties. Oil Crop Sci. 136–141. https://doi.org/10.1016/j.ocsci.2020.08.001

The use of all the listed technological operations allows us to substantiate a comprehensive technology for using flax seeds to obtain various functional properties[84]. The structural features of flax seeds determine the uniqueness of the technological process for obtaining the final product. Flax seeds are small-seeded, the shell of which fits tightly to the kernel, so the stages of fractionation and crushing are not introduced into the technological process. The shell of flax seeds contains a significant amount of valuable nutritional components. Unlike other oilseeds, the shell of flax seeds contains a small amount of cellulose (no more than 18% in terms of dry matter) and up to 62% of other carbohydrates, primarily mucus, which are easily dispersible carbohydrates in water, as well as fats, proteins, and minerals. Preservation of the entire complex of flax seed nutrients in the final product increases its nutritional and biological value.

The seeds undergo triple purification: purification from metallomagnetic impurities in a metallomagnetic separator; purification from organic impurities in an air-sieve separator; removal of mineral impurities on a vibropneumatic stone separator. Thus, the technological scheme includes the following sequence of main stages:

- cleaning of flax seeds from mineral, organic and metallomagnetic impurities;
- short-term washing of flax seeds for 5-10 min;
- heat treatment of flax seeds by convection at T 70 °C for 5 min;
- grinding of food seeds to obtain full-fat flax flour;
- removal of oil from flax seeds by the method of "cold" pressing;
- grinding of defatted flax seeds (flaxseed cake) to obtain semi-defatted flax flour;
- granulation of flaxseed cake;
- additional removal of oil by extraction;
- sieving of ground seeds sequentially on sieves with a hole diameter of 1 mm and 0.5 mm.

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[84] Aliyev, E.B., Mykolenko, S.Yu., Sova, N.A., Aliyeva O.Yu., Malegin R.D., Lupko K.O., Linko, M.O., Ya.V. Gez, Bezugla, L.S. (2022). Technical and technological support for waste-free processing of grain raw materials into food products and feed. Collective monograph. ed. E. B. Aliyeva. Dnipro: LIRA. 192 p. https://surl.gd/uwnflw

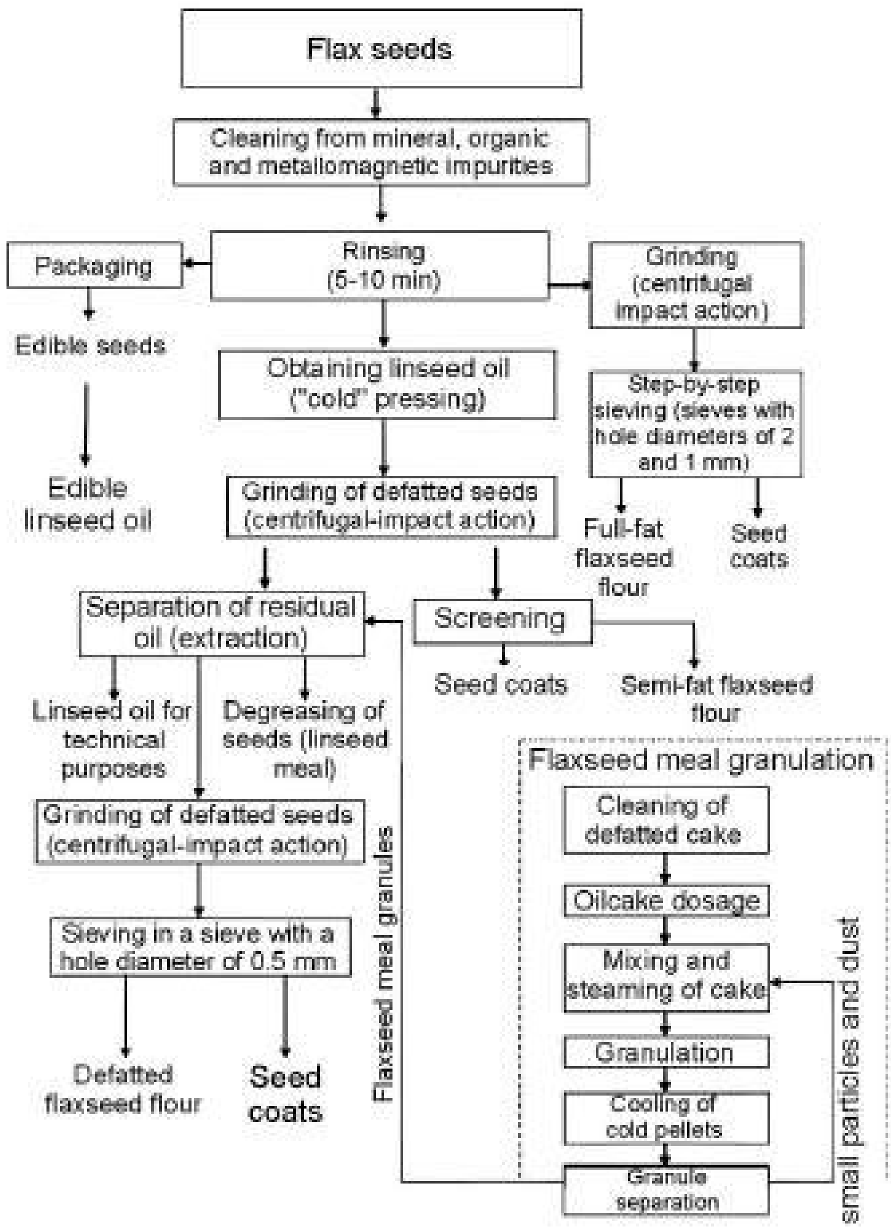

Fig. 23. Technological scheme of complex processing of oilseed flax to obtain products of various functional purposes and raw materials for the production of compound feed

Source: Vegetable oil production technology https://studfile.net/preview/5350038/page:49/

The final products are the following products: edible flax seeds; edible and technical flax oil; full-fat, semi-skimmed and skimmed flax flour. To use the shell fraction with a high content of lignans as a raw material for a biologically active food additive, it must be additionally crushed to a size of no more than 0.4 mm, which is a technological feature of further processing.

From the analysis of the nutritional value of flaxseed oil and seeds, it can be concluded that flaxseed oil and seeds are valuable industrial raw materials that contain many phytochemical properties that increase the biological value of food products. Therefore, the current task of today is the production of functional products from natural raw materials that are safe, affordable, nutritious and beneficial for the human body. Flaxseed oil is one of the natural raw materials that has great potential for the production of food products with a wide range of applications. As noted above, the possibility of growing flax for seeds and oil would provide consumers with products with a large number of nutrients.

Conclusions. The need and feasibility of increasing the volume of oil flax cultivation in the world, as well as in Ukraine, is justified by many factors, in particular the sustainable development of its potential raw material base – the expansion of 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 of using 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 flax straw – the lack of sufficient information on the development and testing of technologies for obtaining fiber with the necessary physical and mechanical characteristics, suitable for the production of technical textiles for reinforcing composite materials. The comprehensive use of flax in industry will also solve 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 flax oil 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 regimes and parameters of the technological process of its primary processing when applying innovative technologies for the complex processing of flax straw stalks.

Thus, based on the analysis of the use of flax oil seeds, it can be concluded that the possibility of using them in the food industry is difficult to overestimate due to the discovery of new properties of the seeds. Therefore, from the point of view of environmental safety and balanced use of nature in agro-industrial production, innovative directions for the use of flax oil seeds will allow filling the Ukrainian market with domestic environmentally safe food products, which have a tendency to be widely implemented in many areas of modern food industry production aimed at the manufacture of innovative food products of various functional purposes.

Based on the analysis of the nutritional value of flaxseed oil and seeds, it can be concluded that this is a valuable industrial raw material with a high content of phytochemical properties, which allows to increase the biological value of food products. Therefore, the current task today is to create functional products from natural raw materials that are safe for humans, which should be affordable, nutritious and useful. Flaxseed oil is one of the natural raw materials that has great potential in the production of food products of a wide range of applications. As noted above, the possibility of growing flax to obtain seeds and oil will provide consumers with products with fiber and vegetable fats.

Analysis of literary sources allows us to conclude that the number of innovative technologies known today that affect the quality of the resulting products is constantly increasing, and methods for determining the quality of new products are insufficient. However, for the development of the flax industry, it is necessary not only to harmonize the existing regulatory framework, but also to study additional consumer properties, taking into account their impact on the human body, namely hygienic, antiseptic, biological properties, as well as energy and therapeutic value. Since in the future this product will be used not only within the country, but also on the European market.

2.7. References

1. Anusudha, V., Sunitha, V. & Mathew, S. (2020). Performance of coir geotextile reinforced subgrade for low volume roads. *Int J Pavement Res Technol*. https://doi.org/10.1007/s42947-020-0325-4

2. Ahrari, M., Karahan, M. & Karahan, N. (2023). Competitiveness Factors in Textiles and Composites Industry and Transformation into Value-Added Products. *Recent – Rezult. Cercet. Noastre Teh*. 24, 132-141. doi:10.31926/recent.2023.70.132

3. Azam, F. & Ahmad, F., et al. (2022). The Role and Applications of Aerogels in Textiles. *Advances in Materials Science and Engineering*, eISSN 1687-8442, Vol. 2022. https://doi.org/10.1155/2022/2407769

4. Ari, A., Karahan, M. & Karahan, N. (2024). Competency Mapping of Textile and Composite Industries*: A Regional-Global Case Study*. eISSN 2065-4529, Vol. 25, is. 1(72), 20-39, https://doi.org/10.31926/RECENT.2024.72.020

5. Ahmad, A., Zulfiqar, S., & Chatha, Z. A. (2020). Development of roasted flax seed cookies and characterization for chemical and organoleptic parameters, *Pakistan Journal of Agricultural Sciences,* 57, 229-235. https://doi.org/10.21162/PAKJAS/20.6552

6. Ahmad, N., Manzoor, M. F., Shabbir, U., Ahmed, S., Ismail, T., Saeed, F., Nisa, M., Anjum, F. M., & Hussain, S. (2020). Health lipid indices and physicochemical properties of dual fortified yogurt with extruded flaxseed omega fatty acids and fibers for hypercholesterolemic subjects. *Food Science & Nutrition,* 8(1), 273-280. https://doi.org/10.1002/fsn3.1302

7. Ahmadniay motlagh, H., Aalipanah, E., Mazidi, M., & Faghih, S. (2021). Effect of flaxseed consumption on central obesity, serum lipids, and adiponectin level in overweight or obese women: A randomised controlled clinical trial. *International Journal of Clinical Practice*, 75(10), e14592. https://doi.org/10.1111/ijcp.14592

8. Akter, Y., Junaid, M., Afrose, S. S., Nahrin, A., Alam, M. S., Sharmin, T., Akter, R., & Hosen, S. Z. (2021). A comprehensive review on Linum usitatissimum medicinal plant: Its phytochemistry, pharmacology and ethnomedicinal uses. *Mini Reviews in Medicinal Chemistry*, 21(18), 28012834. https://doi.org/10.2174/1389557521666210203153436

9. Aliyev, E.B., Mykolenko, S.Yu., Sova, N.A., Aliyeva O.Yu., Malegin R.D., Lupko K.O., Linko, M.O., Ya.V. Gez & Bezugla, L.S. (2022). Technical and technological support for waste-free processing of grain raw materials into food products and feed. *Collective monograph*. ed. E. B. Aliyeva. Dnipro: LIRA. 192 p. https://surl.gd/uwnflw

10. Bayar, G. (2022). Türkiye's sectoral exports: A competitiveness approach. *International Journal of Finance and Economics,* eISSN 2146-4138, Vol. 27, 2268-2289. https://doi.org/10.1002/ijfe.2272

11. Bennato, F., Ianni, A., Innosa, D., Grotta, L., D'Onofrio, A., & Martino, G. (2020). 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*, 33(1), 148-156. https://doi.org/10.5713/ajas.18.0868

12. Cardoso, A.C. (2021). Potencial de própolis no desenvolvimento de têxteis com propriedades funcionais (Potential of propolis in the development of textiles with functional properties). *Master thesis, Universidade do Minho*, Brasil, Dissertacao-PG37988.pdf, https://hdl.handle.net/1822/79512

13. Chand, N. & Fahim, M. (2021). Natural Fibers and their composites; *Tribology of Natural Fiber Polymer Composites (Second Edition).* Paper back ISBN: 9780128189832; eBook ISBN: 9780128190739 http://dx.doi.org/10.1016/S1369-7021(09)70093-8

14. Chursina, L.A., Tikhosova, G.A., Horach, O.O. & Yanyuk,T.I. (2011). Scientific foundations of complex processing of stalks and seeds of oil flax. *Monograph*. Kherson: Oldi-plu. 356 p. https://surl.gd/zkdukm

15. Chursina, L. & Gorach, O. (2020). Classification of technical textiles – the path to quality and safety. *Collection Scientific Bulletin of the Poltava University of Economics and Trade series Technical Sciences* №. 1 (96), 113-120. Goods doi:10.37734/2518-7171-2020-1-14

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

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

18. Drozłowska, E., Łopusiewicz, Ł., Mężyńska, M., & Bartkowiak, A. (2020). The effect of native and denaturated flaxseed meal extract on physiochemical properties of low fat mayonnaises. *Journal of Food Measurement and Characterization*, 14(2), 1135-1145. https://doi.org/10.1007/s11694-019-00363-6

19. Duman, M. (2020). Nutritional value and sensory acceptability of fish burger prepared with flaxseed flour. *Food Science and Technology (Campinas),* 42, e27920. https://doi.org/10.1590/fst.27920

20. Emmanuella, K.T. (2022). A Comparison of financial performance in textile industry: KPR Mill Ltd vs Arvind Ltd. *Business dissertation report,* Pandit Deendayal Energy University, School of Petroleum Management, Gandhinagar, Gujarat, India, http://localhost:8080/xmlui/handle/123456789/539

21. Farag, M.A., Elimam, D.M. & Afifi, S.M. (2021). Outgoing and Potential Trends of the Omega-3 Rich Linseed Oil Quality Characteristics and Rancidity Management: A Comprehensive Review for Maximizing Its Food and Nutraceutical Applications. *Trends Food Sci. Technol*. 114, 292–309. http://dx.doi.org/10.1016/j.tifs.2021.05.041

22. Flax field in Astino: after more than 60 years, a dream came true [Electronic resource]. Access mode: https://www.linificio.it/en/linen-from-astino/

23. Fiber processing equipment [Electronic resource]. Access mode: https://www.textiletechnology.net/news/news/Laroche-Fiber-processing-equipment-13595

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

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

26. Gorach, O. (2023). Current state of production and prospects of the use of oily flax seed in the food industry. Intellectual and technological potential of the XXI century: Innovative technology, Computer science, cybernetics and automation, Architecture and construction, Chemistry and pharmaceuticals. *Monographic series* «European Science». Book 23. Part 1, 41-59. https://doi.org/10.30890/2709-2313.2023-23-01-014

27. Gorach, O., Dzyundzya, O. & Rezvykh, N. (2024). Innovative Technology for the production of gluten-free food products of a new generation. *Current Nutrition & Food Science*. № 20 (6), 734-744. https://dx.doi.org/10.2174/0115734013280307231123055025

28. Global Technical Textiles Market Size, Share, Growth Analysis, By Material, By Manufacturing Process, By Product Form, By Application – *Industry Forecast* 2024-2031. https://surl.li/mkwohl

29. Ghafouri-Oskuei, H., Javadi, A., Asl, M.R.S., Azadmard-Damirchi, S., & Armin, M. (2020). Quality properties of sausage incorporated with flaxseed and tomato powders. *Meat science*, 161, 107957. https://doi.org/10.1016/j.meatsci.2019.107957

30. Ghosal, S., & Bhowal, J. (2021). Bioethanol production from enzymatic hydrolyzates of pretreated flaxseed meals by baker's yeast. https://doi.org/10.21203/rs.3.rs-599700/v1

31. Hägglund, M. (2020). Rebuilding Sweden's crisis preparedness : Lack of clarity impedes implementation. FIIA. *Finnish Institute of International Affairs*, ISSN 1795-8059, Vol. 5, https://www.fiia.fi/wp-content/uploads/2020/05/bp283_sweden_crisis-preparedness.pdf

32. Horach, O.O. & Dombrovska, O.P. (2021). Use of oilseed flax and hemp in the food industry Bulletin of the University of Trade and Economics. Lviv. *Publishing House of the University of Trade and Economics*, 2021. Issue 28. P. 18-22. https://doi.org/10.36477/2522-1221-2021-28-03

33. Holderied, P., Mutschler, T., Tresp, S., et al. (2023). Development of a new yarn supply for weft knitting machines to produce innovative knitwear. *Communications in Development and Assembling of Textile Products*, ISSN 2701-939X, Vol. 4, is. 1, 51-60, https://doi.org/10.25367/cdatp.2023.4.p51-60

34. Horach, O.O., Tikhosova, G.A. & Zabrodina, O.S. (2021). Problems of forming composite materials reinforced with bast fibers *Tovaroznavchy visnyk*: collection of scientific papers. Issue 14. Lutsk: RVV Lutsk National Technical University, 267-274. https://doi.org/10.36910/6775-2310-5283-2021-14

35. Horach, O.O., Dombrovska, O.P. & Chursina, L.A. (2021). Innovative directions of using oilseed flax and ecological safety of food products. Formation of a new paradigm of the development of the agro-industrial sector in the 21st century edited by Avercheva O.V. *Collective monograph*. Kherson: Liga-Press, Volume 2, 593-619. https://doi.org/10.30890/2709-2313.2023-23-01-014

36. Horach, O.O. (2022). Justification of innovative technologies of functional formulations. *Tavria Scientific Bulletin*. Series: Technical Sciences. Kherson State Agrarian and Economic University. Kherson: Publishing House Helvetica, Issue 6, 52-58. http://journals.ksauniv.ks.ua/index.php/tech/article/view/311/287

37. International Trade Administration [Electronic resource]. Access mode: https://www.trade.gov/get-ndustry-updates-textilesapparel

38. Karahan, M., Ahrari, M. & Karahan, N. (2023). Technical Textiles Market Research and Added Value Analysis: A Regio-Global Case Study. Recent – *Rezult. Cercet. Noastre Teh*. 24, 162-180. doi:10.31926/recent.2023.71.162

39. Karahan, M., Ahrari, M. & Karahan, N. (2023). Composite Materials Market Research and Export Potential Analysis: A Regio-Global Case Study. Recent – *Rezult. Cercet. Noastre Teh.* 24, 113-121. http://dx.doi.org/10.31926/RECENT.2023.70.113

40. Karabay, G. & Sarıçoban, K. (2021). Research on Competitiveness in Technical Textiles: Comparison of Countries Having the Lion's Share of Technical Textile World Exports and Türkiye. *Fibres and Textiles in Eastern Europe*, eISSN 2300-7354, Vol. 29, is. 6(150), 22-31, http://dx.doi.org/10.5604/01.3001.0015.2718

41. Khan, S.U., Labonne, L., Ouagne, P. & Evon, P. (2021). Continuous mechanical extraction of fibres from linseed flax straw for subsequent geotextile applications. *Coatings*. 11, 852. [CrossRef] https://doi.org/10.3390/coatings11070852

42. Karahan, M., Ari, A. & Karahan, N. (2024). Examination of R&D Capacity in the Technical Textile Sector: *A Regio-Global Case Study*. eISSN 2065-4529, Vol. 25, is. 1(72), 4-19, https://doi.org/10.31926/RECENT.2024.72.004

43. Kairam, N., Kandi, S., & Sharma, M. (2021). Development of functional bread with flaxseed oil and garlic oil hybrid microcapsules. *LWT-Food Sci. and Technol*., 136, 110300. https://doi.org/10.1016/j.lwt.2020.110300

44. Karwasra, B.L., Kaur, M., Sandhu, K.S., Siroha, A.K., & Gill, B.S. (2021). Formulation and evaluation of a supplementary food (Panjiri) using wheat and flaxseed flour composites: Micronutrients, antioxidants, and heavy metals content. *Journal of Food Processing and Preservation*, 45(1), e14998. https://doi.org/10.1111/jfpp.14998

45. Law of Ukraine № 2697-IX On the Customs Tariff of Ukraine [Electronic resource]. Access mode: https://zakon.rada.gov.ua/laws/show/2697-IX#Text

46. Linseed Oil Production Technology [Electronic resource]. Access mode: https://www.bestoilmillplant.com/linseed-oil-production-technology.html

47. Linseed oil: composition, use, benefits [Electronic resource]. Access mode: https://fitomarket.com.ua/fitoblog/lnjanoe-maslo-sostav-ispolzovanie-polza

48. Marand, M.A., Amjadi, S., Marand, M. A., Roufegarinejad, L., & Jafari, S.M. (2020). Fortification of yogurt with flaxseed powder and evaluation of its fatty acid profile, physicochemical, antioxidant, and sensory properties. *Powder Technology*, 359, 76-84. https://doi.org/ 10.1016/j.powtec.2019.09.082

49. Mezrea, P.E., Ispir, M., Balci, I.A., et al. (2021). Diagonal tensile tests on historical brick masonry wallets strengthened with fabric reinforced cementitious mortar. *Structures*, eISSN 2352-0124, Vol. 33, 935-946, https://doi.org/10.1016/j.istruc.2021.04.076

50. Mushtaq, B., Ahmad ,A., Ali Z., et al. (2022). Core Spun Based Helical Auxetic Yarn: A Novel Structure for Wearable Protective Textiles. *Journal of Natural Fibers*, ISSN 1544-0478, Vol. 19, is. 16, 15058-15070, https://doi.org/10.1080/15440478.2022.2070322

51. Nagaraja, S., Anand, P.B., & Ammarullah M.I. (2024). Synergistic advances in natural fibre composites: a comprehensive review of the eco-friendly bio-composite development, its characterization and diverse applications. *RSC Advances*, vol. 14, no. 25, 17594-17611. https://doi.org/10.1039/d4ra00149d

52. Nguyen, T.T. & Indraratna, B, (2023). Natural fibre for geotechnical applications: concepts, achievements and challenges. *Sustainability* 15(11):8603. https://doi.org/10.3390/su15118603

53. Nitish, K., Ramesh, K.K. & Surender, S. (2022). Effective utilization of natural fibres (coir and jute) for sustainable low-volume rural road construction – A critical review. *Constr Build Mate*r 347:128606. https://doi.org/10.1016/j.conbuildmat.2022.128606

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

55. Offer – The main magazine on agribusiness https://propozitsiya.com/ua/ harchoviy-napryam-vikoristannya-lonu-oliynogo

56. Official Website of the International Trade Administration [Electronic resource]. Access mode: https://www.trade.gov/sites/default/files/2020

57. Park, H. (2022). The Current State of the Korean Technical Textile Industry and Tasks for Policy. *KIET Industrial Economic Review*, ISSN 1598-947X, Vol. 27, is. 2, 19-29, Paper № 22/IER/27/2-2. http://dx.doi.org/10.2139/ssrn.4190717

58. Pervaiz A., Azam F. & Ahsan A. (2024). Investigation of Static and Dynamic Mechanical Properties of Eco-Friendly Textile PLA Composites Reinforced by Flax Woven Fabrics *International Journal of Polymer Science*. https://doi.org/10.1155/ijps/2821777

59. Qiu, C., Wang, H., Guo, Y., Long, S., Wang, Y., Abbasi, A.M., Guo, X. & Jarvis, D.I. (2020). Comparison of Fatty Acid Composition, Phytochemical Profile and Antioxidant Activity in Four Flax (Linum usitatissimum L.) *Varieties. Oil Crop Sci*. 136-141. https://doi.org/ 10.1016/j.ocsci.2020.08.001

60. Shahata Hassan, N., Ahmed, Sadek M., Said & Shamandy, E. (2019). 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*. eISSN 2357-0342, is. 19. https://doi.org/10.21608/mjaf.2019.13553.1198

61. Sanmartin, C., Taglieri, I., Venturi, F., Macaluso, M., Zinnai, A., Tavarini, S., Botto, A., Serra, A., Conte, G., Flamini, G., & Angelini, L. G. (2020). Flaxseed cake as a tool for the improvement of nutraceutical and sensorial features of sourdough bread. *Foods,* 9(2), 204. https://doi.org/10.3390/foods9020204

62. Sapozhnikov, A. N., Kopylova, A. V., Gurova, D. V., & Bolshakov, K. A. (2021). Obtaining of gluten-free pizza dough based on flaxseed flour. IOP Conference Series: *Earth and Environmental Science* 677(3), 032056. https://doi.org/10.1088/17551315/677/3/032056

63. State Register of Plant Varieties Suitable for Distribution in Ukraine [Electronic resource]. Access mode: https://sops.gov.ua/ua/derzavnij-reestr

64. Techtextil i Texprocess 2022 [Electronic resource]. Access mode: https://surl.li/cyrgaz

65. The return of flax cultivation to the United States [Electronic resource]. Access mode: https://surl.gd/peimeq

66. Toulabi, T., Yarahmadi, M., Goudarzi, F., Ebrahimzadeh, F., Momenizadeh, A., & Yarahmadi, S. (2021). Effects of flaxseed on blood pressure, body mass index, and total cholesterol in hypertensive patients: A randomized clinical trial. *Explore.* https://doi.org/10.1016/j.explore.2021.05.003

67. Umair, M., Ullah, T., & Nawab, Y. (2023). 3D Natural Fiber Reinforced Composites in Natural Fibers to Composites. *Engineering Materials*. *In book*: Natural Fibers to Composites, 41-78. http://dx.doi.org/10.1007/978-3-031-20597-2_3

68. Varietal resources of oilseed flax [Electronic resource]. Access mode: https://propozitsiya.com/ua/sortovi-resursi-lonu-oliynogo

69. Wirkijowska, A., Zarzycki, P., Sobota, A., Nawrocka, A., Blicharz-Kania, A., & Andrejko, D. (2020). The possibility of using by-products from the flaxseed industry for functional bread production. *LWT Food Science and Technology*, 118, 108860. https://doi.org/10.1016/j.lwt.2019.108860

Abstract

The monograph highlights the results of scientific research on the comprehensive use of oil flax, presents the general and agrotechnological characteristics of oil flax, problems and prospects for the use of bast and fiber obtained from oil flax stems in industry. The results of research on the use of oil flax seeds and oil in the food industry, as well as methods of oil production, are presented. It is shown that the sown areas of oil flax have increased significantly, which is due to the widespread use of flax seeds in the pharmaceutical industry abroad and in Ukraine to produce biologically active additives. Production and scientific research indicate that oil flax is a promising crop, and it is economically feasible to increase the sown areas. However, unfortunately, the stems of this crop are almost never used in industry. Oil flax straw is mostly burned in the fields, therefore, in modern conditions, the development of new resource– and energy-saving technologies for processing oil flax straw is relevant.

Based on the above, it can be concluded that the issue of integrated use of oil flax will allow to increase the profitability of growing oil flax and will contribute to solving the phenomena in the domestic energy sector and the problem of raw material supply for many industries. Integrated use of oil flax in industry will also contribute to solving the problems associated with the shortage of raw materials obtained from such technical crops as long flax, cotton and hemp.

Keywords: oil flax, straw, bast, fiber, technical textiles, seeds, oil, food industry.