

ADVANTAGES OF USING BAST FIBER RAW MATERIALS IN ORTHOPEDIC PILLOWS

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Abstract: This article analyzes the possibility of using oil flax and technical hemp fibers as fibrous fillers in orthopedic pillows. The primary quality properties of these fibers were determined and compared with various types of fillers most commonly used in orthopedic products. A convenient pillow shape was developed that would correspond to the anthropometric parameters of the human body. Thanks to its bone-like shape, this pillow can be universal, suitable for different parts of the human body. Additionally, fabrics for pillowcases were analyzed, and material options were proposed that would improve the functional properties of the orthopedic product. Experimental samples of orthopedic pillows were also developed and tested for wear resistance, ease of use, dimensional stability, and healing properties for patients undergoing rehabilitation after injuries and illnesses. These products performed excellently during use. According to doctors and users, they are comfortable, maintain their shape over time, are durable, and effective in treating bedsores and healing wounds. Numerous studies have shown that ordinary down products and pillows with low-quality filling often cause spinal curvature, leading to pinched nerves, headaches, and other unpleasant symptoms. An orthopedic pillow allows for a full and healthy rest. These products conform to the curves of the human body during rest, sleep, travel, and treatment, and subsequently return to their original state. This effect allows for the even distribution of load on the spine, preventing posture distortions.

Keywords: oil flax fibers; hemp fibers; properties; orthopedic pillow; pillowcase; anthropometric shape; therapeutic effect.

1 Introduction

An orthopedic pillow is not only a means for comfortable rest but also an effective aid in medical institutions. Orthopedic pillows help in the fight against bedsores, work as a means for the rehabilitation of patients after limb amputation, and serve as a preventive measure, providing comfort and rest during pregnancy. Numerous studies have shown that ordinary down products and pillows with low-quality fillers often cause spinal curvature and, as a result, pinched nerves, headaches, and other unpleasant painful manifestations [9]. An orthopedic pillow allows for a full and healthy rest. Such products conform to the curves of the human body during rest, sleep, travel, and treatment, after which they return to their original state. This effect allows for an even distribution of the load on the spine, preventing the development of posture curvatures.

There are many different materials from which orthopedic pillows can be made, but in recent years, consumers have preferred natural products. Bast fiber raw materials (flax, hemp) have already proven themselves as quality and environmentally friendly materials for making pillowcases for pillows and blankets. However, this type of raw material is used much less frequently as a fibrous filler. To use oil flax and hemp fibers after the decortication process as a filler for pillows, their properties were studied, which will provide comfortable, healthy sleep, quality treatment, and rehabilitation for their owner.

Great attention during the manufacture of orthopedic pillows is paid to their shape and production technology. Only by correlating anthropometric properties, filler quality, and the production process of these products can a therapeutic effect and comfortable feeling be achieved.

The relevance of this work lies in the fact that the market for orthopedic products is oversaturated with low-quality products made from synthetic materials that can cause irreparable harm to human health. The use of natural, environmentally friendly fillers, which, thanks to their quality properties, will make the orthopedic product effective in the treatment and prevention of

various diseases, combined with a universal shape, is a relevant scientific endeavor today. Thus, to obtain a high-quality product with orthopedic and therapeutic effects, all components of production must be taken into account: filler, top material, and manufacturing technology.

2 Literature review

Works on the study of the properties of bast fiber raw materials, namely flax and hemp fibers, are carried out constantly. Many foreign and domestic scientists have devoted their scientific works to the problem of studying the influence of physical and mechanical characteristics of hemp and flax fibers on finished products: Didukh and Yaheliuk (2022) [7], Boiko (2022) [2], Berezovsky (2020) [1], Velmurugan (2022) [15], Grégoire (2021) [8], Baretc, Ouagne, and Barthod-Malat (2017) [12]. The studied type of raw material is used in various industries: food, textile, pulp and paper, automotive and aircraft construction, as composites, non-woven materials, geotextiles, etc. As a fibrous filler, technical hemp and oil flax fibers are also used in pillows, mattresses, and blankets, but this material has not yet been used in orthopedic products.

Given the high demand for orthopedic products at present in Ukraine, conducting research aimed at determining the suitability of bast fiber raw materials as a fibrous filler in orthopedic pillows is an urgent and timely task.

3 Materials and methods

The work on developing a multifunctional, effective, durable, high-quality orthopedic pillow involves several stages. The first stage is to determine the possibility of using oil flax and technical hemp fibers as fibrous fillers. The second stage is to create a universal shape for an orthopedic product that would be multifunctional and suitable for different parts of the human body. Finally, it is necessary to select a pillowcase fabric that would not suppress the properties of the filler but instead make the product aesthetic, ecological, practical, safe, and of high quality.

The main criterion when choosing orthopedic products with different fillers is the raw material composition of both the top material (cover) and the filler, as the quality of the finished product, as well as its safety, depends on them. Therefore, the conducted research was based primarily on identifying the quality properties of the components of the bast fiber filler, which will improve the therapeutic, functional, ecological, and ergonomic properties of the product and increase its shelf life.

In the laboratories of Kherson National Technical University and Khmelnytskyi National University, studies of the components of the bast fiber filler—fiber mass of oil flax and technical hemp—were conducted to use these fibers as fillers in orthopedic pillows for various functional purposes. Literature sources indicate that these fibers possess many quality properties. One of the biggest advantages of hemp and flax fiber as fibrous fillers is their ecological nature. Flax and hemp crops are among the most resistant plants known to mankind and are grown without the use of pesticides and chemical fertilizers. This makes products using them safe for health and the environment [2].

These fibers have excellent heat and moisture retention properties. Hemp and oil flax fibers have a unique structure that allows them to retain heat and simultaneously conduct air well. They retain heat in cold weather and allow the skin to breathe and not overheat in summer [2].

Additionally, oil flax and hemp fibers have natural antibacterial properties that help combat the development of bacteria and fungi. These properties of the fibers aid in the fight against bedsores and promote wound healing.

Another unique property of the studied bast fiber raw material is moisture regulation, i.e., the ability to absorb and evaporate

moisture. This helps regulate humidity levels in bed and ensures a comfortable rest. Additionally, they prevent the formation of unpleasant odors and mold.

Through the cottonization of hemp and flax fiber, a soft, pleasant-to-touch filler is obtained, which is able to maintain the shape of the pillow due to its density. Such products have a pleasant texture to touch and provide softness and comfort during sleep and rest. They adapt well to the body shape and distribute pressure, helping to reduce muscle tension and improve the body's condition.

These fibers have good natural thermoregulation. Pillows with such filler will help maintain the body's natural thermoregulation, allowing a comfortable temperature regime throughout the entire time of use.

Regarding the shelf life of products with such fibrous filler, durability and stability are ensured for several years. Orthopedic pillows with this type of filler will be distinguished by high strength and resistance to wear. They can serve a person for many years without losing quality and shape. This makes this type of product ideal for those who value durability and economy.

Significant savings in the technological process of manufacturing fibrous filler can be obtained by removing the bleaching and dyeing operations, as hemp and flax fibers as a filler may not go through these stages. They have their own natural aesthetic appearance and style. If pillowcases made from this type of raw material are also used in sleeping products, they will have a natural, organic look, adding a special charm to the bedroom. Bast fiber filler for orthopedic pillows is a natural, ecological, and healthy component for products that will provide comfort during treatment and rest.

4 Results

To determine the special advantages of the studied type of filler for orthopedic pillows, a comparative analysis of the most common fillers for orthopedic pillows was conducted. There are many fillers for orthopedic pillows, including synthetic, artificial, and natural fibers, as well as buckwheat hulls, millet, rice, orthopedic foam, latex, and gels with a cooling effect [13]. Each of these fillers has both advantages and disadvantages. For the comparative analysis, the following fibrous fillers were selected: polyester fiber, down/feather, buckwheat hulls, oil flax fibers, and technical hemp fibers. Table 1 presents a comparative analysis of the selected fibrous fillers based on the following properties: hygroscopicity, air permeability, antibacterial properties, wear resistance, filler strength, product height without load, and product height under load. All studies of filler properties were conducted according to standard methodology [4; 5; 3].

Table 1: Comparative analysis of fillers for orthopedic pillows

No	Indicator	Down /Feather (92/8%)	Polyester fiber	Buck-wheat hulls	Oil flax fibers	Hemp fibers
1.	Filler strength, cm ³ /g	0.30	0.24-0.27	0.25-0.28	0.30-0.31	0.32
2.	Product height without load, cm	19	17-18	10	15	15
3.	Product height under load, cm	10-11	8-9	7-8	14.5	14
4.	Air permeability, dm ³ /m ² s ≥ 20	15.3	20.2	25.0	31.2	33.0
5.	Hygroscopicity, % ≥ 6.0	6.0	7.3-7.5	7.5-8.0	11.0-12.0	15.0
6.	Antibacterial properties	absent	absent	present	present	present
7.	Wear resistance, years	1-2	2-3	2-4	7-9	7-9

Analyzing the data, we can conclude that fibrous fillers from oil flax fibers and technical hemp have significant advantages over

other fillers used in orthopedic products. The table did not include synthetic fillers like holofiber and sintepon due to their hygroscopicity being equal to 1%. As seen from the table, natural fillers have excellent air permeability and hygroscopicity, with the highest indicators observed in oil flax fibers and technical hemp fibers. Due to the morphological structure of oil flax and technical hemp fibers, which contain numerous air channels, these fibers provide high air permeability and ventilation. Additionally, the shelf life of products with these fillers is the longest for flax and hemp fibers, which is attributed to their properties.

Another notable advantage is the density of the fibers, which enhances the functional properties of the product. During use, the pillow will better retain its shape, resist lumping, remain comfortable, and maintain its original appearance. Thus, we can conclude that this orthopedic product will not only be ecological, aesthetic, and functional, but also hypoallergenic and long-lasting.

One of the problems with pillows containing natural fillers is the potential development of microorganisms and dust mites during prolonged and improper use. This can lead to various skin rashes, redness, or even serious issues like bronchial asthma [16]. Given the natural qualities of oil flax and technical hemp fibers, dust mites and pathogenic microorganisms, bacteria, and fungi are unlikely to develop in them. Such pillows are an excellent option for individuals suffering from allergic diseases.

The next stage of work focused on developing an orthopedic pillow shape that would be universally suitable for different parts of the human body. Orthopedic pillows have a special shape that conforms to the body's curves and provides optimal support for the head and neck during rest.

The orthopedic product is designed to address and improve the problems described above. The anatomy of the human body requires support for the head and cervical vertebrae in a horizontal position for comfortable rest. Elevated support helps prevent pain and spinal curvature. Modern orthopedic pillows often feature an increased roller along one of the long (horizontal) sides, the size of which must be selected individually based on the width of the person's shoulder. It is also essential to select the required curve individually to ensure the anatomical pillow supports the head well and prevents it from rolling during rest. Furthermore, the orthopedic effect should contribute to:

- Correct positioning of the neck and spine according to physiology;
- Normal blood circulation of the vessels in the cervical region;
- Absence of tension in the muscles of the upper spine;
- Prevention of varicose diseases;
- Rehabilitation after amputation or limb fractures;
- Prevention of bedsores;
- Comfort during prolonged sitting and rest.

Considering the above and the anatomical forms of humans, a universal pillow shape was developed, resembling a "bone." The proportions of this pillow were calculated for a person of standard size. The pillow has three facets with rounded edges and a curve in the middle. Additionally, for the convenience of use by people with disabilities, special handles were developed on the sides to make it easy to pull or adjust the product. A graphic image and pattern of the pillow according to the developed template are presented in Figure 1 a, b.

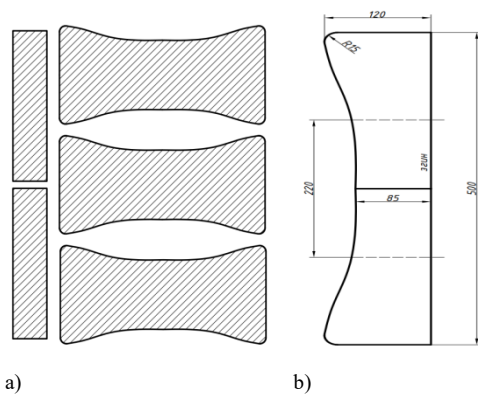


Figure 1. a) graphic image of the orthopedic pillow pattern; b) orthopedic pillow cut.

As seen in Figure 1, the cut of this orthopedic product consists of five parts: three main parts of the bone-shaped pillow and two handle-grips. This product was assembled with ordinary seams and ironing. The seams were not processed, and seam allowances were 1 cm. The quilting method, often used for making orthopedic products with artificial or wool fibers, was not employed in this case. The main disadvantage of the quilting method is that the filler can form voids or lumps during use. Therefore, this method was not used for the manufacture of this product. Graphic images of the seams used for sewing the orthopedic product are presented in Figure 2.

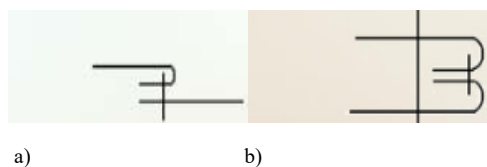


Figure 2. Graphic image of seams used for the orthopedic pillow: a) seam with ironing for joining the main parts of the product, b) double seam for joining the handle-grips of the product.

The use of seams depicted in Figure 2 ensures the strength of the orthopedic product's seams. During use, these seams will not cause discomfort, and the product's aesthetics will be preserved. The threads used for joining the parts are 100% cotton No. 90, compliant with the European standard EN 12590:1999 and certified with the Oeko-Tex® Standard 100 [11].

For this product, a pillowcase made of thin calico can be used, allowing for easy cover changes and ironing. To facilitate this, a hidden zipper will be sewn into one of the facets of the bone-shaped pillow. The zipper will extend the length of the concave facet, from one handle-grip to the other. This design feature will simplify cover changes and enhance the operational and aesthetic properties of the orthopedic pillow.

The fabric of the cover plays a crucial role in ensuring that the product has an aesthetic shape, is pleasant to the touch, does not cause allergic reactions, is durable, and maintains quality properties. The cover material should be strong, abrasion-resistant, hygienic, and comfortable. Various fabrics are used in the production of orthopedic pillows, including natural, artificial, and synthetic options. Commonly used fabrics include different types of cotton, linen, viscose, velour, microfiber, and polyester.

To understand the quality properties of cover fabrics for orthopedic pillows, the most frequently used fabrics were evaluated based on indicators such as relative total thermal resistance, hygroscopicity, air permeability, and strength [14]. The fabrics studied included cotton, linen, polyester, and bamboo. Experiments were conducted following standard methodologies [6; 5].

Table 2: Comparative analysis of covers for orthopedic pillows

No.	Indicator	Cotton	Linen	Polyester	Bamboo fabric
1.	Air permeability, $\text{dm}^3/\text{m}^2\text{s}$	25.0	29.8	31.7	27.0
2.	Hygroscopicity, %	15.0	18.2	0.4	20.1
3.	Relative total thermal resistance, $\text{m}^2 \text{ }^\circ\text{C}/\text{W}$	0.316	0.380	0.278	0.312
4.	Surface density, g/m^2	511	230	536	535

The analysis of the tabular data indicates that natural fiber fabrics exhibit superior properties for pillow covers. Cotton fabrics are soft to the touch but have less durability compared to linen and polyester fabrics. Linen fabrics, though durable, have a coarser texture that may cause discomfort. Thermal resistance is comparable across all studied fabrics. Polyester fabrics have significantly lower hygroscopicity than natural fibers, which could adversely affect the therapeutic efficacy of the orthopedic product.

Fabrics used for pillow covers must have adequate wear resistance [10], primarily ensured by abrasion resistance. Literature suggests that not only the fiber composition but also the fabric structure—including the surface layer properties of the yarn, bond strength among structural elements, and their elastic properties—affects abrasion resistance. There is some debate about the impact of weave type on abrasion resistance. While some research suggests that plain weave fabrics are most resistant to abrasion, other studies indicate that they are less resistant. Consequently, the fabric weave was not a primary focus in the selection of materials for the orthopedic pillow covers.

Thus, natural fabrics such as linen and various types of cotton (e.g., calico, poplin, muslin, satin) are recommended for orthopedic pillow covers. These fabrics should possess high strength, density, and wear resistance due to their weave and repeat patterns.

Following the conducted research, experimental orthopedic pillows were developed for use in medical settings for the rehabilitation of patients with limb and full-body injuries. After a month of use, it was observed that the pillow's shape makes it versatile for supporting various body parts. The orthopedic pillow can be used under the head, neck, arms, or legs, or for lying sideways, making it multifunctional. Additionally, the use of oil flax fibers and hemp fibers as fillers has been shown to facilitate rapid wound healing, reduce the risk of bedsores, and stabilize the patient's condition. Examples of these orthopedic pillows with oil flax and technical hemp fillers are illustrated in Figure 3.



Figure 3. Example of the use of orthopedic pillows in medicine

5 Conclusion

Based on the results of the conducted research, the key properties of fibrous fillers made from oil flax and technical hemp fibers have been identified. Comparative analysis of these bast fibers with other common fillers, such as polyester fiber, down/feather, and buckwheat hulls, reveals that the oil flax and hemp fibers offer notable advantages. These fibers exhibit high air permeability and hygroscopicity, attributed to their morphological structure which includes numerous air channels. This structure enhances air flow and ventilation. Additionally, the longevity of products using these fillers is superior, a reflection of their intrinsic properties. The density of these fibers also contributes to better functional characteristics of the product.

ensuring that the pillow maintains its shape, resists lump formation, and remains comfortable and aesthetically pleasing over time. Consequently, these orthopedic products are not only eco-friendly, aesthetically pleasing, and functional but also durable and non-allergenic.

A universal shape for the orthopedic pillow has been developed, designed to accommodate various parts of the body. This pillow features a bone-like shape with three facets, rounded edges, and a central curve. To enhance usability, handles are incorporated on the sides of the pillow, facilitating ease of use for individuals with limited mobility. The manufacturing process includes using seams with ironing for joining the main parts and a double seam for the handle parts.

Various fabrics used for pillow covers were analyzed, including cotton, linen, polyester, and bamboo fabric. The analysis showed that while cotton fabrics are soft, they are less durable compared to linen and polyester. Linen fabrics, though durable, are coarser and may be uncomfortable. Thermal resistance was comparable across all fabrics, but polyester exhibited lower hygroscopicity, which could adversely affect the pillow's therapeutic properties. It is recommended to use natural fabrics for pillow covers due to their strength, density, and wear resistance, as well as their natural comfort and safety attributes.

Experimental samples of orthopedic pillows were tested for wear resistance, ease of use, shape stability, and therapeutic efficacy for patients in rehabilitation. The results indicated that these pillows performed excellently, maintaining their shape over time, proving durable, and effectively aiding in the treatment of bedsores and wound healing.

The pillow can be equipped with a thin calico pillowcase to facilitate easy cover changes or ironing. A hidden zipper sewn into one of the facets of the bone-shaped pillow will enhance both its operational and aesthetic properties.

In summary, the developed orthopedic pillows offer numerous advantages over existing products. They serve as versatile orthopedic tools suitable for various body parts and functional purposes.

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Primary Paper Section: F

Secondary Paper Section: FI, JJ