# METHODS FOR IMPROVING THE QUALITATIVE INDICATORS OF FABRIC ON THE BASIS OF HEMP COTONINE FOR THE TOP OF FOOTWEAR

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***Abstract:*** *Every year there is a growing interest in the use of technical hemp in light industry, not only abroad, but also in Ukraine. Many native entrepreneurs in the production of textiles use natural, environmentally friendly hemp fibers. This is due to the high quality properties of the fibers of this culture. Hemp fiber has great wear resistance and strength, even when compared to linen or cotton fibers. Hemp fibers have high hygroscopic properties Due to the porous structure of hemp fiber, the fabric obtained from it is able to absorb moisture up to five hundred percent of its weight. Also, these fibers are hypoallergenic. But, with such quality indicators, hemp fiber has a high breaking elongation; this negatively affects the performance properties of footwear. This article analyzes all the factors that negatively affect the shape stability of the shoe upper fabric, based on technical hemp fibers: high relative breaking elongation of hemp cottonin - 17.2%; fibrous and percentage composition of warp and weft threads in shoe upper fabrics and the weave of the shoe upper fabric. Based on the above experimental studies, a number of scientific hypotheses have been proposed that will help solve the negative impact of the above factors on the performance properties of industrial hemp footwear. The implementation of these hypotheses will improve the quality of native products made from industrial hemp and make them competitive in the domestic and European markets.*

***Keywords:*** *steaming, hemp cottonin, physical and mechanical properties, shoe products.*

## 1 INTRODUCTION

At present, the efficiency of Ukrainian light industry enterprises is rather low, the goods produced by enterprises in this industry are significantly inferior in quality and quantity of products of developed countries [1]. The lack of domestic raw materials leads to overpricing and encourages the sale of products made of synthetic and chemical fibers of poor quality. The increase in prices for natural foreign raw materials leads to an increase in the cost of finished products even at the initial stage of their manufacture. Given the global economic instability, not all segments of the population can afford to consume high-quality products from natural raw materials, since there is a pattern: an increase in product quality leads to an increase in its cost.

To create environmentally friendly goods with high consumer characteristics at an affordable price, it is necessary to have high quality domestic raw materials. Industrial hemp is an additional source of raw materials for Ukraine. Hemp fibers are very strong and have high antiseptic and hygienic properties, which have a beneficial effect on the human body [2].

Today Ukraine has potential opportunities for the development of the hemp processing industry. These are, first of all, favorable natural and climatic conditions for growing industrial hemp and obtaining high yields of fiber and seeds, the presence, albeit of an outdated material and technical base. Also, in Ukraine, highly productive varieties of hemp have been created, which are not inferior, but on the contrary, surpass varieties of another traditional culture for Ukraine - flax in all yield indicators.

The number of Ukrainian enterprises processing hemp is increasing every year. The needs of the modern consumer for environmentally friendly products stimulate entrepreneurs to produce more and more new products from hemp fiber raw materials. Clothes and footwear made from hemp fibers are in great demand because products, made of hemp fibers, have high sanitary and hygienic properties, which provide regular heat exchange and have a positive effect on the spine and musculoskeletal system of the human body [2]. Hemp fabrics have high air permeability, which contributes to the retention of oxygen in the structure of textiles, excluding the development of anaerobic bacteria and the possibility of their reproduction inside various types of clothing, knitwear, shoes, etc. But along with the positive aspects of hemp fiber in textiles, problems arose with some of the properties of the fibers in the products during their use - this is the loss of dimensional stability. This moment is especially strongly reflected in footwear, thus, with the high needs of the modern consumer in textile products from domestic natural raw materials.

## 2 LITERATURE REVIEW

Hemp is known to contain ultra-strong and long fibers. The use of such fiber in the yarn, without modification, does not impart the softness of a cotton fiber to textiles. The leading manufacturers of hemp fiber textiles in the world have solved this problem long ago and widely use modified hemp cottonin. Modern equipment for processing hemp fiber into a modified one is produced by the companies "Laroche" (France), "Temafa" (Germany), "HempFlex" Romania, as well as the technology of the Institute of Agricultural Engineering named after V.I. Leibniz (Germany) [3]. The essence of the fiber modification process consists in special processing of bast fibers to transform them into a material similar in structure to cotton, in order to obtain the possibility of processing it using cotton technology [4]. When preparing bast fibers for spinning, attempts are made to remove cellulose satellite substances from them, which can have a negative effect on the spinning process and yarn properties. For example, fats and waxes have a positive effect in the spinning process, the influence of proteins, ash and pentosan can be neglected, but the encrusting substances must be removed. The task of modern technologies for cottonization of hemp fiber is to obtain cottonin with an insignificant degree of contamination, the linear density of which is close to the linear density of the fibers, intended for mixing or for obtaining multicomponent yarns [5]. Known methods of cottonization are: mechanical, chemical, biological and physical.

At Ukrainian enterprises for the production of clothing and footwear, hemp cotonin of mechanical processing is used. But products made from it, especially shoes, have some disadvantages. After few time of usage, footwear loses its dimensional stability [6]. Therefore, the scientists of the Kherson National Technical University were tasked with identifying the causes of this defect and finding ways to eliminate it.

Scientific research on improving the quality properties of footwear was highlighted in the works of domestic and foreign scientists Baidakova L., Dudla I., Konoval V., Libi V., Nesterov V., Polovnikov I., Rybalchenko V., in general or specific aspects. Basically, these studies are devoted to the anthropo-morphological features of the feet of the population, materials science (leather, or imitation leather), the design and technology of footwear production [7-9]. But the study of the characteristics of the fiber, the study of hemp fiber upper fabrics and the occurrence of negative factors during operation for dimensional stability have not yet been considered. Therefore, the determination of ways to eliminate negative factors on the performance properties of footwear made of technical hemp is relevant for the solution.

## 3 RESEARCH METHODOLOGY

The tasks were solved using the methods and means of theoretical and experimental research, which make it possible to get a complete picture of the physical and mechanical structure of hemp fibers and make it possible to formulate practical conclusions and recommendations for changing their properties for the further introduction of this raw material into textile production.

Experimental studies were carried out on the basis of the research laboratory for the processing of natural fibers of the Department of Commodity Science, Standardization and Certification and the Laboratory of Textile Materials Science of the Department of Expertise, Technology and Textile Design of the Kherson National Technical University.

One of the objectives of this scientific work is the study of cottonized hemp fiber (*Gljana variety*). This grade is characterized by high fiber performance. Under the conditions of the Lyutinsky hemp plant, from this variety of industrial hemp, hemp cottonin was obtained by the traditional method of mechanical modification, which is the only source of domestic products for obtaining textiles.

The first stage of research was aimed at determining the physical and mechanical properties of the resulting fiber [10]. Due to the lack of standard methods for assessing the quality of hemp cotton, methods for assessing the quality of fibers used for cottonized flax and cotton were used to determine the main physical and mechanical parameters.

## 4 RESULTS AND DISCUSSION

First, the length of the hemp cottonin was determined. Since cottonized hemp fiber has significant unevenness in length, the characteristics of fiber groups were used to assess its unevenness: maximum, average and minimum length. Results of studies are given in Table 1.

**Table1** Hemp cottonin fiber length groups

| Maximum length 120-90 mm | Average length 80-60 mm | Minimum length 50-1 mm |
|---|---|---|
| 30% | 55% | 15% |

Based on the results of the main groups of fiber lengths, hemp cottonin has an average length of about 70 mm, which is greater than the staple length of medium staple cotton. This indicator does not allow using the obtained cottonin for the production of yarn using the cotton spinning system. At the same time, the percentage of short fibers and down is 15%, spun fibers - 75%, with a length of more than 10 mm - about 7%, which corresponds to the normative indicators for spinning using the short flax technology.

In addition to the analysis of the length, studies were carried out on the strength and linear density of hemp cottonin. Due to the fact that hemp cottonin has a high strength due to the content of a high percentage of lignin (up to 8%), more than that of other bast crops, and also has a large elongation, due to the high fat content of 3%, therefore, determine it according to the regulatory documentation for hemp fiber, it makes no sense. All tests were carried out in accordance with the cotton regulations. The test results are shown in Table 2.

**Table 2** Qualitative indicators of hemp cottonin

| № | Indicator | Indicator value |
|---|---|---|
| 1. | Breaking load of one fiber [gf] | 42.0 |
| 2. | Absolute breaking elongation [mm] | 10.6 |
| 3. | Relative breaking elongation [%] | 17.2 |
| 4. | Linear density [tex] | 6.8 |

It is known that on the equipment of cotton processing enterprises using a carded spinning system, fibers with a linear density of 0.16-0.33 tex with a cross-sectional size of 15-19 microns are used. The resulting cottonin fiber has a linear density of 6.8 tex, which is 20 times higher than the standard cotton fineness. So, the hemp cottonin obtained using this cottonization technology does not correspond to the indicators of medium staple cotton in terms of thickness and cannot be used to obtain thin and soft yarn.

Analyzing the strength of hemp cottonin fiber, which is one of the most important indicators of its quality, from the data in Table 2, it can be concluded that the breaking load of cottonin is 39.5 gf greater than the maximum breaking load of medium-staple cotton fibers. So, hemp cotton fibers exceed cotton fibers by 95% in breaking load. Also, the elongation at break of hemp cotton is 17.2% with such an indicator 100 percent use of this raw material in yarn for form-stable products is not recommended. It is possible to select blends with other fibers or use various treatments of cottonized fiber to reduce this indicator.

It is also possible to use long hemp fiber for shoe upper fabrics, since the relative breaking elongation of the fibers is 5-9%, but as you know, the linear density of such fiber is 25-50 tex, which means that these fibers will be coarse and yarn from they will differ in their thickness. Thus, the use of this fiber in the upper yarn will spoil the appearance and comfort of the product. Compared to cottonin, which has a linear density of 6.8 tex, long hemp fibers are much inferior to hemp cottonin in terms of aesthetics and comfort for textiles. Thus, the use of long fibers in the upper yarn is possible, but not effective. Therefore, hemp cottonin was used for further research.

For this purpose, the scientists carried out the steaming of raw materials in a laboratory autoclave. At this stage of the experiment, in addition to steaming, the operations of boiling and washing hemp raw materials were added. The material was steamed under the following conditions:

- pressure: heating, cooking 1.2-7.1 kgf/cm$^2$, steaming 1.8-2.3 kgf/cm$^2$, washing 0 kgf/ cm$^2$;
- temperature: heating, cooking 90-160°C, steaming 140-121°C, washing 40°C;
- operation duration: heating, boiling for 30 minutes, steaming for 20 minutes, washing for 10 minutes.

After steaming, repeated tests were carried out physical and mechanical parameters of hemp cottonin fiber. The results of quality indicators of fiber after steaming hemp cottonin are shown in Table 3.

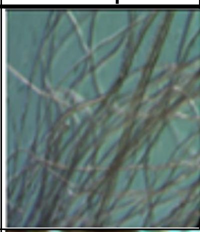
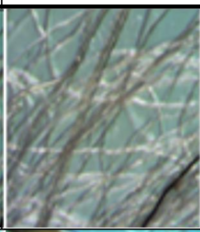
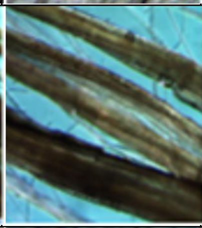
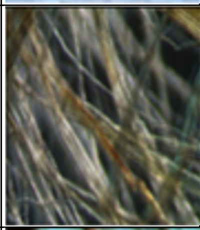
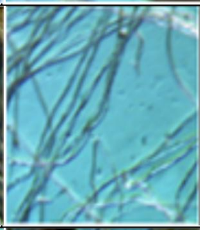
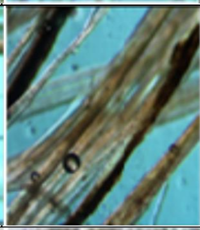
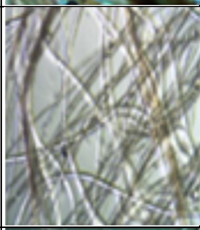
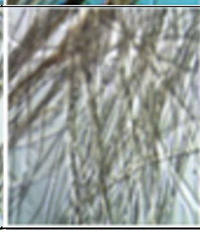
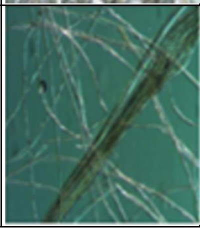
**Table 3** Qualitative indicators of hemp cottonin after fiber steaming

| № | Indicator | Indicator value |
|---|---|---|
| 1. | Breaking load of one fiber [gf] | 34.01 |
| 2. | Absolute breaking elongation [mm] | 5.3 |
| 3. | Relative breaking elongation [%] | 9.3 |
| 4. | Linear density [tex] | 5.5 |

Studies have shown a significant decrease in the elongation at break, by almost half. This is due to a decrease in the fat wax up to 1% in the chemical composition. Also, the linear density has decreased, which also has a positive effect on the quality of the final textile product. A small reduction in breaking load does not have a large impact on the quality of the resulting fiber. From which it follows that steaming hemp cottonin changes the chemical composition with the redistribution of the molecular bonds of the fiber, which has a positive effect on the physical and mechanical properties of the hemp fiber.

After improving the properties of hemp fiber, the next stage of research was aimed at determining the fibrous composition of samples of fabrics for shoe uppers based on hemp cottonin and their weave, imported to Ukrainian shoe enterprises. For a more detailed determination of the basic composition of tissues, the method of light microscopy was chosen. Research data are highlighted in Table 4.

**Table 4** Fibrous composition and weaving of imported fabric samples

| № | Sample | Weave type | Photo of fiber microstructure | | Fibrous composition [%] |
|---|---|---|---|---|---|
| | | | Warp | Weft | |
| 1. |  | The two-faced weave is formed from three systems of threads; of two warp yarn systems and one weft yarn system |  |  | On the warp cotton 60%, hemp 40% On the weft cotton 60%, hemp 40% |
| 2. |  | Plain weave in which the warp and weft threads overlap each other in every two successive overlaps |  |  | On the warp hemp is harsh 100% On the weft hemp is harsh 100% |
| 3. |  | Two-faced weave is formed from three systems of threads: from one system of warp threads and two systems of weft threads |  |  | Based on hemp 100% The weft is 100% cotton |
| 4. |  | Plain weave in which the warp and weft threads overlap each other in every two consecutive overlaps |  |  | Based on hemp 100% The weft is 100% hemp |
| 5. |  | The reverse twill, in contrast to the base twill, has a scar direction from right up to left. |  |  | On the warp hemp 70%, wool 30% On the weft hemp 70%, wool 30% |
| 6. |  | Plain weave in which the warp threads overlap each other in each successive overlap |  |  | Based on cotton 70%, hemp 30% On the weft cotton 70%, hemp 30% |

Based on the results of previous studies of experimental wearing of shoes made of these hemp-based fabrics, a change in the dimensional stability of finished products was revealed. This is due to the high rate of elongation at break of hemp cottonin 17.2%. To reduce this indicator, mixtures with other fibers are used, but in this case, the above proposed mixtures do not have a positive effect on the dimensional stability of finished products.

The next stage of research was to determine the linear density of the threads in the fabrics along the warp and weft. The research results are shown in Table 5. The tissue samples in the Table 5 are numbered from the previous Table 4.

As can be seen from Table 5, only the sixth sample has a small linear density, which indicates the thinness and softness of this shoe upper fabric, the rest of the samples will look rough on the finished product. The manufacturers of these fabric samples decided to reduce its elongation by increasing the linear density of the yarn, but due to the high content of hemp cottonin in the mixtures without steaming, this indicator did not decrease, and the aesthetic characteristics deteriorated. Thus, the imported fabrics based on hemp fibers, which are currently used at the enterprises of the footwear industry in Ukraine, lead to a decrease in the competitiveness of domestic footwear made from environmentally friendly raw materials.

**Table 5** Determination of linear density of tissue samples

| Fabric samples | Linear density [tex] | |
|---|---|---|
| | On the basis | Weft |
| 1 sample | 102 | 104 |
| 2 sample | 720 | 744 |
| 3 sample | 184 | 60 |
| 4 sample | 324 | 340 |
| 5 sample | 248 | 260 |
| 6 sample | 48 | 52 |

## 5 CONCLUSIONS

Based on the results of the studies, by steaming the fiber in the above modes, hemp cottonin fiber with an improved tensile elongation index was obtained. The indicators of this characteristic have halved from 17.2% to 9.3%, but this indicator is still large. The use of this fiber in a mixture with other fibers will make it possible to improve the dimensional stability index in future products.

Based on the studies carried out, the following working hypotheses were proposed to increase the form stability index of hemp fabric for the upper of shoes:

- into the mixture of hemp cottonin it is proposed to introduce lavsan fiber in various percentage compositions up to 40%. This percentage of synthetic fibers will reduce yarn elongation and will not interfere with the natural characteristics of the finished fabric;
- it is proposed to take cotton threads on the warp of the weave report and on the weft above the proposed hemp-lavsan mixture. The introduction of cotton fiber into the composition along the base will provide the fabrics for the upper of the shoe with a more uniform weave pattern, the fabric will be softer and more elastic, which will have a positive effect on the appearance of the product during operation;
- the use of twill weave in various variations (classic, reinforced) to determine the most relevant, in order to increase the dimensional stability. After all, as you know, twill weave is the most durable and form-stable, therefore it is usually used in the production of denim.

The implementation of these scientific hypotheses will solve the problems with the operation of shoes made of hemp fabrics. After all, the main factors of negative impact on the fabric of the upper of the shoe will be solved by a mixture of hemp with synthetic fibers and twill weave.

On the warp of the conducted scientific work, it was found that due to the steaming of hemp cottonin of the mechanical modification method, under certain conditions; it is possible to improve the physical and mechanical characteristics of fibers. Applying this fiber treatment in practice, it is possible to improve the dimensional stability of future products.

Also, while the analysis of the studies carried out on samples of imported fabric for the upper of footwear based on technical hemp has established that the reason for the low dimensional stability of finished footwear depends on many factors. The main problem is the low relative breaking load of hemp cottonin. In addition, the percentage composition of the warp and weft threads and the type of weave has a negative effect on dimensional stability. Therefore, to solve these problems on the basis of experimental studies, a number of scientific hypotheses have been proposed, the implementation of which will contribute to an increase in the operational life of the shoe without changing the appearance and its size. Based on this, we can conclude that the use of hemp cottonin in a mixture with lavsan fiber in the shoe industry.

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