DEVELOPMENT & RESEARCH ON CONSUMER PROPERTIES OF INTEGRATED TWO-LAYER WEFT KNITTED FABRIC FROM ECO-RAW MATERIALS

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Abstract: *Nowadays a lot of people pay attention to various aspects that can preserve and improve their health and standard of living. Therefore, ecological knitwear of a functional purpose made of natural raw materials becomes popular. The authors developed the structure and proposed the set factors for producing the integrated knitted fabric where hemp or nettle yarn will be used to form one of the layers in two-layer knitwear. Such fabric may be used as a functional textile material for manufacturing the linen products of medical treatment and preventive care, in particular for the underwear of wounded servicemen during their treatment and rehabilitation. The new structure is a two-layer fabric with forged connection of layers by main threads. Connecting forged yarn-overs in the fabric are arranged in staggered manner. At places of connecting yarn-overs, blind holes are generated; they provide ventilation and rapid water removal from under the clothes. In the research, it is determined how the type of eco-raw material of one of the layers in integrated two-layer knitwear influences on the linear dimensions of knitwear, the relaxation properties, the level of capillarity and the change in the liquid level in time.*

Keywords: *eco-textiles, environmentally friendly knitwear, hemp yarn, nettle yarn, knitwear, multifunctional knitwear.*

1 INTRODUCTION

The variety of chemical composition and physical-mechanical properties of raw materials makes it possible to obtain knitted materials with predefined properties. A number of experiments are conducted in our laboratories in order to study various physical and mechanical properties of knitted fabric made from natural yarn and to change their properties when this yarn is combined with modern, artificially manufactured components for creating multifunctional knitwear.

Along with such widely known types of natural raw materials as cotton and wool, nowadays items from little-known and still poorly studied types of ecologically pure raw materials become popular. This may be yarn from eucalyptus, banana, coconut, soy, bamboo, maize, hemp and nettle. Along with antibacterial and antiseptic properties, such materials have positive preventive and sometimes also therapeutic effect on a person. From the point of view of tactile sensations, eco-materials do not irritate the skin, and do not become electrified. If eco-raw materials are used to form a functional layer of integrated knitwear, then textile material of medical treatment and preventive care will be formed. In particular, such materials will be helpful for the underwear for wounded servicemen during their treatment and rehabilitation, as well as for use in field operations during warfare.

The purpose of this work is to develop & research consumer properties of integrated two-layer weft knitted fabric from eco-raw materials. In experimental studies, we planned to find out the influence of the type of eco-raw material on the technological shrinkage of integrated knitwear, deformation properties and capillarity.

2 MATERIAL

The advantages of eco-yarn from hemp and nettle over the cotton are obvious. Hypoallergenic properties (very low allergenic capacity) of this yarn are achieved due to the absence of toxic chemicals in the raw materials; these chemicals may be used to control weeds, plant pests and diseases of cultivated plants. The costs of growing hemp and nettle are relatively small while therapeutic and environmental effects are beneficial. Items from hemp yarn are widely used now. Products from this yarn have high consumer and hypoallergenic properties. They create a temperature and energy balance, have antiseptic, wound-healing and anti-allergic functions. Thanks to the porous structure, hemp fibre retains heat and absorbs moisture (it allows the body to breathe during heat). Contact with endocrine glands has rather positive effect on nervous and cardiovascular systems. Hemp fibre reflects ultraviolet radiation. Medical scientists have proved that treatment of small wounds and scars with dressing material from hemp fibre speeds up the healing process by three times. The reason is that hemp fibre retains up to 20% of the oil in its composition; this oil is an effective wound-healing agent [1-3].

But hemp fibre is quite tough and non-uniform in thickness. A large amount of admixtures (a large percentage of inclusions in fibre) complicates the situation. If the yarn is rewound, the influence of these factors is reduced. Thanks to the waxing, the yarn becomes more uniform. To improve the knitting capacity of hemp yarn, moisturizing is necessary.

Little-known raw materials from nettle also have health benefits. It is proved that nettle products help with illness, such as headache and pain in joints. Nettle items improve blood circulation; have a calming effect on the nervous system; favourably affect sleep, overall well-being and even the mood of a person (joy, calmness and confidence); cause pleasant feelings. They help to cope with depression, loss of energy and fatigue. These items have a favourable effect on biologically active points, that is, they harmonize the work of inner parts of human body. They have a warming effect due to which they help to eliminate the inflammatory and stagnant processes in the body. That’s why people use nettle belts and plates as the first aid from pain [4-6].

Nettle raw materials are treated in the same way as flax. The production of nettle yarn is not complicated but it is rather time-consuming [2].

The above mentioned facts enable us to speak of high hygienic properties of knitted fabric made from hemp and nettle yarn. As eco-raw materials from nettle and hemp have advanced medical properties, it is very important to expand the range of their further use, including in underwear for medical treatment and preventive care.

Adequate quality of knitwear is an important problem in the production of special-purpose clothing. Quality parameters of such clothing (sport, underwear, protective), including therapeutic effect, are determined by such consumer properties as changes in linear dimensions after washing, relaxation parameters and capillarity. If the influence of the raw material type in integrated knitwear layers on its consumer properties is determined, then it will ensure the production of knitwear with predefined quality.

A number of scientists tried to the forecast the sorption capacity of knitted fabric with a hydrophobic synthetic polyester thread [1-7]. The authors of the paper draw conclusions about the influence of the knitting density, the special features of structure formation and the type of raw material on the sorption capacity of knitted fabrics. The ability of a knitted fabric to remove vaporous moisture from a human body to the outside of a linen or protective item is an important factor that influences bodily comfort [8, 9]. Therefore, it is necessary to examine the influence of raw materials of integrated knitwear on capillarity and the method of moisture withdrawal.

There is also no information on the influence of these types of eco-raw materials as a hydrophilic layer of integrated knitwear on its functional properties.

3 EXPERIMENTAL

3.1 Material

Despite all the positive features, hemp and nettle fibres are very non-uniform in thickness and quite tough. That’s why these materials are not widely used in knitwear. A lot of admixtures in hemp and nettle make it almost impossible to process these yarns on knitting equipment. Therefore, it is necessary to conduct further research in order to find out parameters that provide normal process of stitch formation [10].

The authors developed technology for production of integrated two-layer knitwear with forged connection of layers by main threads; this technology is produced for the two-bar circular knitting machine. In the fabric, the connecting yarn-overs are arranged in staggered manner. At places of connecting yarn-overs, blind holes are generated; they provide ventilation and rapid water removal from under the clothes.

Graphical record of the weave structure in two-layer knitted fabric is presented in Figure 1.

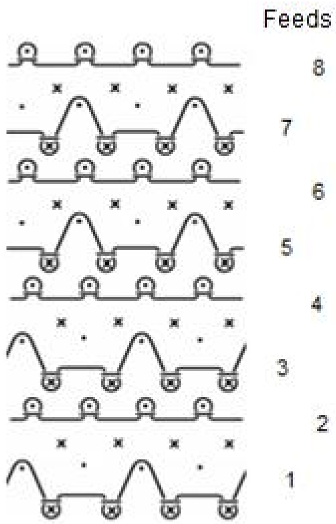

Figure 1 Weave structure (graphical record)

This structure makes it possible to obtain knitted fabric with a clear distinction of functional layers. One layer is of synthetic threads (for withdrawal of vaporous moisture from underwear), the other – of natural one (absorbing and rapidly evaporating moisture). The authors suggest that hemp or nettle yarns should be used as raw materials for hydrophilic layer in two-layer knitwear; these yarns provide therapeutic and preventive properties of knitted fabric.

To form a hydrophobic layer, it was decided to use anti-allergic polyester thread with high capillary capacity. This thread also provides elasticity, shape retention and thermal regulation; it also makes these items attractive to consumers. Moreover, this type of raw material is inert to the development of pathogenic microflora due to its hydrophobic property, it does not absorb extraneous odours and dirty spots may be easily removed during washing.

The set factors for fabric in the developed functional samples are presented in Table 1.

Table 1 Set factors for knitted fabrics

Sample No.	Type of raw materials in knitting system	Linear density [tex]
1	1, 3, 5, 7 Feeds – hemp yarn	25X2
	2, 4, 6, 8 Feeds – polyester thread	16.7
2	1, 3, 5, 7 Feeds – nettle yarn	31X2
	2, 4, 6, 8 Feeds – polyester thread	16.7

The samples were made on a two-bar circular knitting machine of 16th class with a ribbed arrangement of needles. To improve the knitting capacity of hemp and nettle raw materials, the yarn was rewound three times. The rewinding of the yarn made it possible to remove its admixtures and non-uniformity in thickness. In order to reduce the flexural rigidity of the yarn, it was moistened before knitting.

3.2 Shape stability

Shape stability is an important consumer property of sport and linen knitted fabric. These fabrics have to retain their shape in everyday use and after multiple washing cycles. Shrinkage parameters of knitted fabric patterns (removed from machine) after washing and drying are determined according to a standard procedure [11].

In this research, the authors determined in which way the type of eco-raw material influences linear dimensions (technological shrinkage after washing and drying) of the samples of integrated two-layer knitwear after washing and drying. Parameters of developed functional fabrics before and after the first washing are presented in Table 2.

As a result of the first washing, shrinkage of knitted fabric removed from machine took place both along the length and width. The diagrams shown in Figure 2 illustrate the average values of technological shrinkage parameters of knitted fabrics (removed from machine) after the first stage of washing and drying (confidence probability 95%). The following washing did not cause further change in linear dimensions of samples.

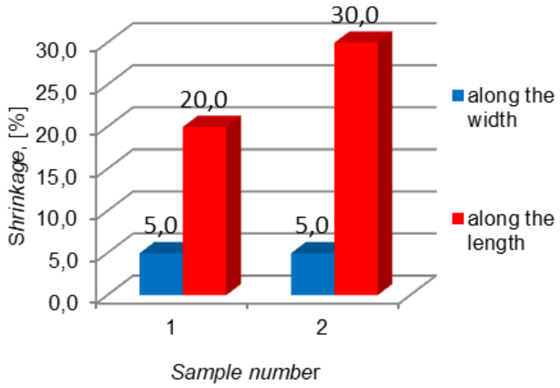

Figure 2 Technological shrinkage of knitted fabric removed from machine after the first stage of washing and drying

In this research it was found that technological shrinkage along width after washing and drying does not depend on the type of eco-raw material of the hydrophilic layer and is equal to 5%. The peculiarities of structure formation in two-layer knitwear, namely the presence of connecting forged yarn-overs, may explain considerable shrinkage along the length, about 20-30%. Significant shrinkage along the length is also caused by moistening of the yarn. When moistened, the connecting yarn-overs (formed from the raw material of considerable rigidity) are aligned due to elastic properties of the thread.

The kind of eco-raw material of the hydrophilic layer in the integrated two-layer knitwear affects the technological shrinkage along the length after washing and drying. If hemp yarn is changed to nettle yarn, then shrinkage along the length of knitwear is increased by 50%. The reason is that nettle yarn has the greater flexural rigidity compared to the hemp yarn.

Significant shrinkage along the length leads to increase in surface density: sample 1 - by 40%, sample 2 - by 70%. The increase in surface density after washing leads to an increase in material consumption of the product. To reduce the shrinkage along the length and, correspondingly, the surface density, it is necessary to reduce the frequency in arrangement of the connecting yarn-overs along direction of knitting.

Table 2 Parameters of knitted fabrics

Sample No.	Before washing			After washing		
	number in 100 mm of knitwear		surface density m_s [g/m^2]	number in 100 mm of knitwear		surface density m_s [g/m^2]
	wales	*courses*		*wales*	*courses*	
1	75	95	255	80	130	355
2	80	90	242	85	130	411

3.3 Deformation characteristics

Shape stability of knitwear may be evaluated based on the known components of the deformation relaxation: fast-moving, slow-rotating and residual. The deformation properties of the samples are determined according to standard procedure [12]. In determining tensile strain of knitwear, the load value was constant and equal to 6 N. The results of the research are presented as graphs (see Figures 3 and 4).

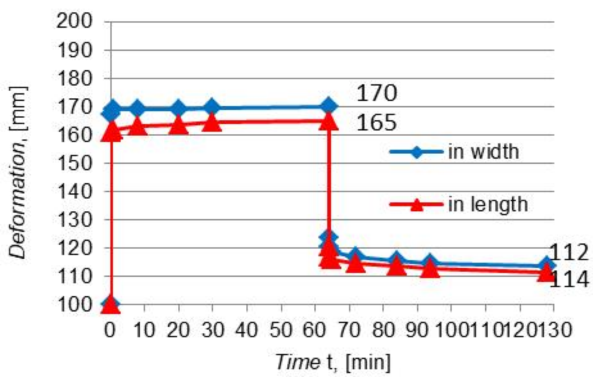

Figure 3 Deformation and relaxation of deformations for the sample 1

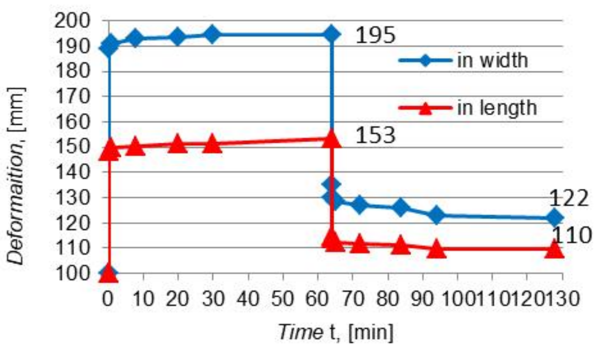

Figure 4 Deformation and relaxation of deformations for the sample 2

As can be seen from the graphs (Figures 3, 4), deformation of samples of knitted fabrics at a load of 6 N is similar. Both for the hemp and nettle yarns, the total deformation in tension along the width (along the wale) is greater than along the length (along the course). However, in sample 2, it varies up to 3%. Compared to sample 1, the total deformation in width is 15% greater, in length - 7% smaller. The residual deformation of the prototypes is within the range 18-23%. This indicates a sufficient elasticity and shape stability of knitted fabrics. Greater part of residual deformation when sample 2 is stretched along the length (by 15%) may be explained by the greater flexural rigidity of the nettle yarn and the greater coefficient of friction for the thread-by-thread, which prevents the reverse process of thread redistribution from the sticks of the hinges to the slip stitch. The diagrams presented in Figures 5 and 6 clearly illustrate the components of the deformation relaxation of the samples. Knitted fabric, where the face layer is produced from nettle yarn, is less shape-stable in length. The obtained results make it possible to predict the behaviour of knitwear under service loads.

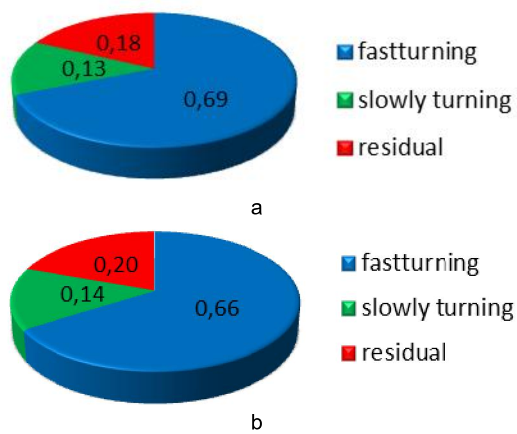

Figure 5 Components of deformation in sample 1 along width (a) and length (b)

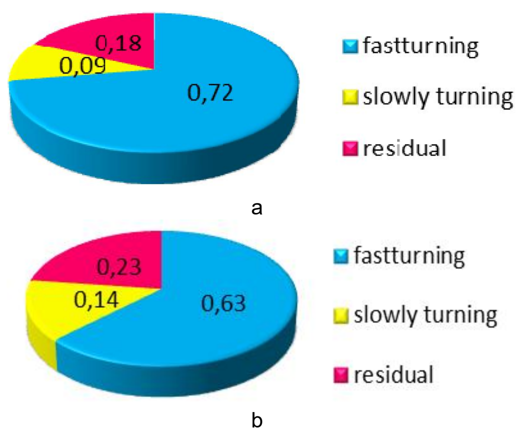

Figure 6 Components of deformation in sample 2 along width (a) and length (b)

3.4 Capillarity

To determine capillarity means to measure the height of the capillary rise of the coloured liquid in 60 minutes' experiment along vertically placed sample of two-layer knitwear. Capillarity of the developed samples of bicomponent two-layer knitwear was examined according to the standard procedure [13]. Capillarity of the developed knitted fabric samples is determined along the wales (along the width of fabric) and the courses (along the height of fabric) both from the hydrophilic side and from the side of the hydrophobic layer. Table 3 shows the average values for the rising in liquid level along the courses and wales in case of hydrophilic layer from hemp yarn (sample 1).

Table 3 Results for raising the liquid level in time, sample 1

Duration of experiment [min]	Raising of liquid level from the side of hemp layer [mm]		Raising of liquid level from the side of polyester layer [mm]	
	along courses	along wales	along courses	along wales
5	5.5	5.6	4.4	2.9
10	7.5	8.4	5.8	4.3
15	9.3	9.3	6.2	5.1
20	10.2	10.1	6.6	5.3
25	10.9	10.8	6.9	6.3
30	11.6	11.5	7.2	6.7
35	12.2	12.1	7.4	7.2
40	12.4	12.5	7.6	7.4
45	12.6	12.9	7.8	7.7
50	12.9	13.1	8.0	8.0
55	13.1	13.4	8.2	8.2
60	**13.3**	**13.6**	**8.3**	**8.4**

To clearly visualize results of research and to determine in which way the height of liquid level depends on the time of experiment, appropriate graphs are generated (see Figures 7 and 8).

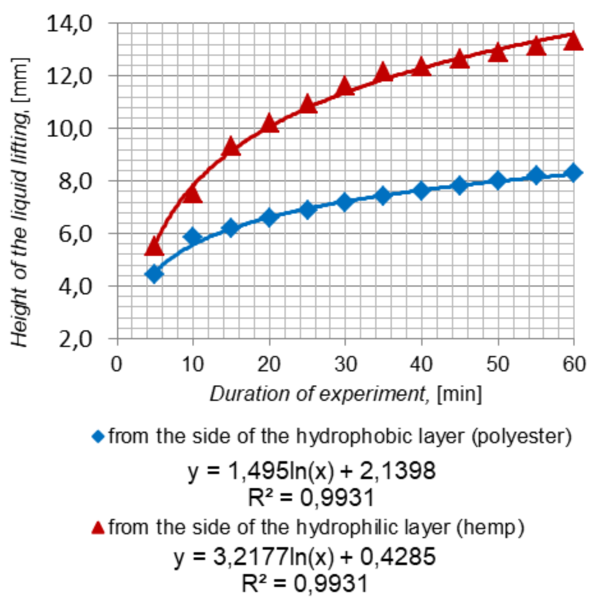

Figure 7 Raising the liquid level along the courses, sample 1

As seen from the graphs, the liquid level from the side of the hydrophilic layer (hemp yarn) is higher than from the hydrophobic side (polyester thread). It is explained by the capillary properties of the raw material.

The difference in liquid levels at the 60th minute of experience, which corresponds to the level of capillarity, along courses is 5.0 mm, along the wales - 5.2 mm. The level of capillarity along the wales is higher because of the high degree of thread orientation in stitches in the direction of wales.

During experiment, the liquid level from the side of the hydrophilic (hemp) layer along the courses is increased by 141.8%, along the wales - by 142%; from the side of the hydrophobic layer (polyester) along the courses - by 88.6%, along the wales – by 189.7%. Thus, the dynamic of liquid level raising from the hemp layer side does not depend on the direction of experiment. But from the side of the hydrophobic layer, the speed of liquid level raising along the wales is more than 2 times higher than along the courses. This may be explained by considerable shrinkage along the length and an increase in fitting density in connecting forced yarn-overs from the side of the hydrophilic layer (hemp yarn).

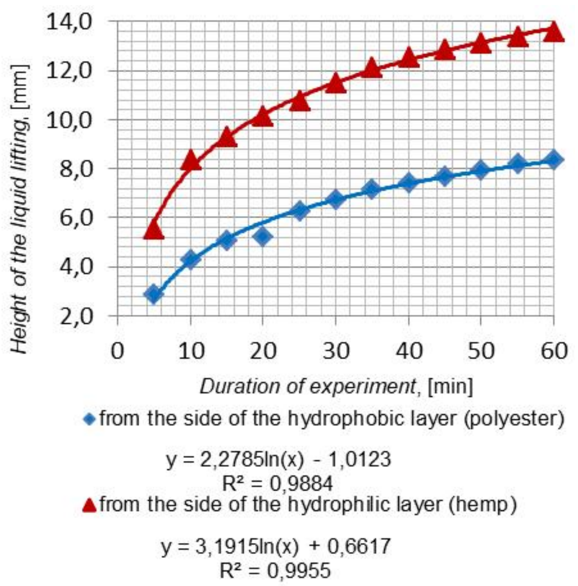

Figure 8 Raising the liquid level along the wales, sample 1

Table 4 shows the average values of liquid level raising along the courses and wales in case of formation of the hydrophilic layer from the nettle yarn (sample 2). Based on the data in Table 4, graphs are generated (see Figures 9 and 10).They clearly illustrate in which way the raising of liquid level depends on the time of experiment.

Table 4 Results for raising the liquid level in time, sample 2

Duration of experiment [min]	The liquid raising from the side of the hemp layer [mm]		The liquid raising from the side of the polyester layer [mm]	
	along the loop rows	along the loop columns	along the loop rows	along the loop columns
5	6.2	5.5	5.8	3.9
10	7.9	7.6	6.9	5.1
15	9.5	8.8	7.9	6.3
20	10.4	9.6	8.4	7.1
25	11.2	10.4	8.8	7.6
30	11.7	11.0	9.1	8.1
35	12.1	11.3	9.5	8.5
40	12.3	11.6	9.8	8.7
45	12.6	11.9	10.2	9.0
50	12.8	12.2	10.4	9.2
55	13.1	12.6	10.7	9.5
60	**13.3**	**12.8**	**10.9**	**9.7**

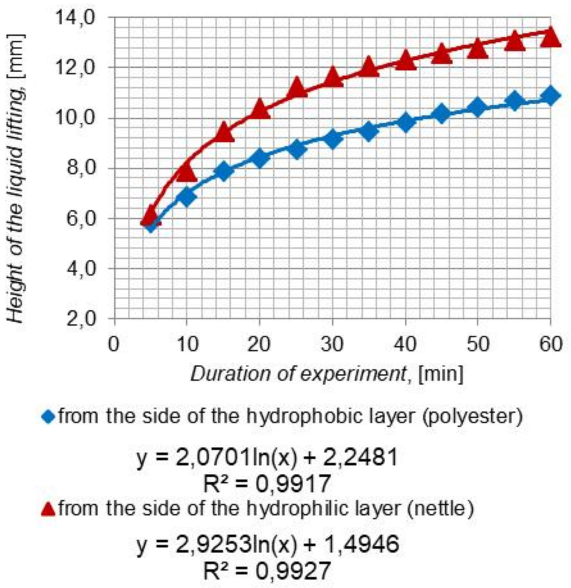

Figure 9 Raising the liquid level along the courses, sample 2

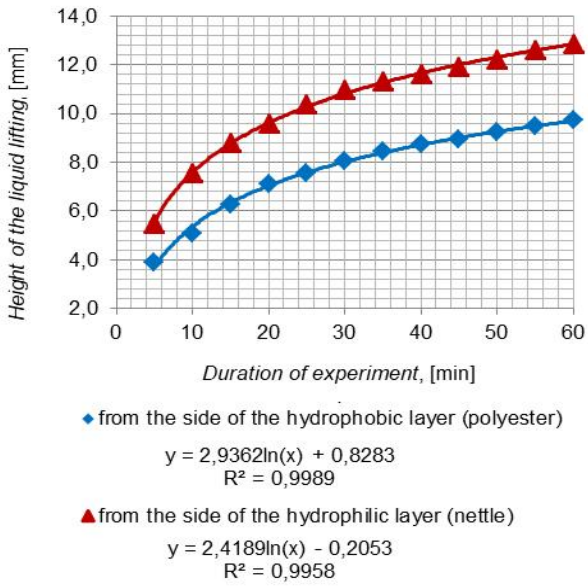

Figure 10 Raising the liquid level along the wales, sample 2

As seen from the graphs, as in sample 1, the liquid level from the side of the hydrophilic layer along the courses and wales is higher than from the side of the hydrophobic layer. The liquid level from the side of the hydrophilic layer along the wales is 15% lower than along the courses.

During experiment, the liquid level from the side of the hydrophilic (nettle) layer along the courses is increased by 114.5%, along the wales - by 132.7%; from the side of the hydrophobic layer (polyester) along the courses - by 87.9%, along the wales – by 148.7%. Thus, the dynamic of liquid level raising along the wales is higher than along the courses. And for a hydrophobic layer, the height of the liquid level raising along the wales is almost 2 times higher than along the courses. This is explained by considerable shrinkage of the knitted fabric along the length (30%).

The indicator of capillarity level of textile material is the height of liquid level at the 60th minute of the experiment. According to the data obtained in Tables 3 and 4, the corresponding capillarity diagrams along the course and wale (Figures 11, 12) are generated; they clearly illustrate the influence of the type of raw material (from which the hydrophilic layer of integrated two-layer knitwear is formed) on the level of capillarity.

As can be seen from the diagrams presented in Figure 11, the capillarity from the hydrophilic layer does not depend on the type of eco-raw material. This may be explained by the same vegetable origin of hemp and nettle eco-raw materials. Moreover, the direction in which capillarity was determined is insignificant. The level of capillarity both along the wales and courses is almost the same.

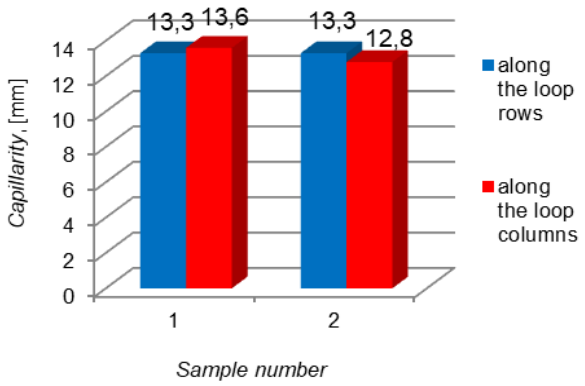

Figure 11 Diagrams of capillarity of the developed samples of two-layer bicomponent knitwear from the side of the hydrophilic (hemp or nettle) layer

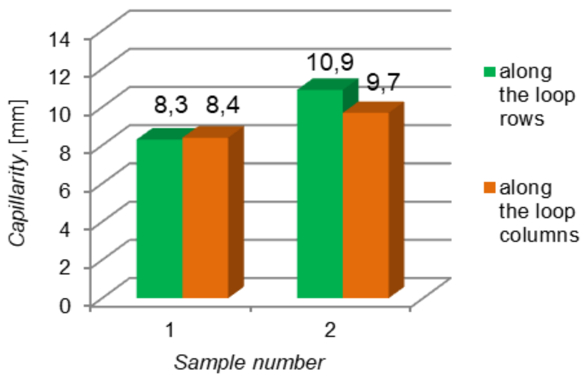

Figure 12 Diagrams of capillarity of the developed samples of two-layer bicomponent knitwear from the side of a hydrophobic (polyester) layer

Connecting elements (from hydrophilic raw materials) that are present in the structure of two-layer knitwear influence the capillarity of hydrophobic layer. However, the type of eco-raw material in the hydrophilic layer (from which connecting yarn-overs are formed) has an influence on the capillarity level from the hydrophobic layer. If the hydrophilic layer is formed from the nettle material, then the capillarity level on the side of hydrophobic layer increases along the courses by 31%, along the wales - by 15.5% (Figure 12).

A greater shrinkage along the length of bicomponent knitwear (where nettle yarn and connecting yarn-overs from it are used as a hydrophilic layer) may be explained by the fact that elastic properties of the yarn appear in horizontal stretches, in particular, by considerable flexible rigidity of the yarn.

4 CONCLUSIONS

When developing bicomponent knitted fabrics in order to form functional properties, special attention should be paid to the type of raw material from which the hydrophilic layer of integrated knitwear is formed. To develop textile material for the items of medical treatment and preventive care, it is advisable to use such eco-raw materials as hemp and nettle.

In experiments on consumer properties of the developed samples of integrated two-layer knitwear, the influence of the type of eco-raw material on linear dimensions was determined. When nettle yarn (from which connecting yarn-overs of the two-layer knitwear are formed) is used for a hydrophilic layer, the shrinkage along the length is increased by 50%. This is due to a significant flexural rigidity of nettle yarn compared to hemp. The deformation properties of knitted fabric are determined. The part of residual deformation (that indicates the shape stability of textile material) is the same along the width of samples and is equal to 0.18. But the part of residual deformation along the length of sample 2, produced from nettle, is more by 15%. The higher coefficient of thread-by-thread friction in the nettle yarn prevents the deformation relaxation. Obtained results enable us to predict the behaviour of knitwear under service loads.

In the study on capillarity, the influence of type of eco-raw material on the capillarity level of samples is determined. The change in liquid level is determined in time over the functional layers of the integrated two-layer knitwear using the eco-raw material as the hydrophilic layer. The results of studies on the water-absorbing properties of bicomponent two-layer knitwear testify that type of raw material of the hydrophilic layer has an influence on the capillarity level from the hydrophobic side. It was found that the capillarity in sample 2 from the side of the hydrophobic layer is higher than that of sample 1: along the courses - by 31%, along the wales - by 15.5%. More significant influence in the direction of the courses is explained by the transverse direction of the formation of stitches from one yarn in the course of knitwear.

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