Romualda Marszałek, Barbara Binkowska, Andrzej Sapieja, Teresa Hernik, Bożenna Marcinowska

Modification of Linen Fabrics with Health Promoting Products and its Effect on the Use Properties of the Fabrics and Natural Environment

Institute of Natural Fibres and Medicinal Plants
ul. Wojska Polskiego 71 B, 60-630- Poznań, Poland
E-mail: romualda.marszalek@iwnirz.pl

Abstract
The study involved the determination of the effect of the modification of linen fabrics with health promoting products containing different substances such as vitamin E, beeswax and natural silk protein on the use features of the fabrics and their biodegradation. It was found that enriching linen fabrics with health promoting products contributes to the improvement of their touch, does not have a negative effect on the biodegradation process nor the whiteness degree and the modification effect is resistant to 10 cycles of care processes. The modification causes a decrease in the breaking force and thread slippage index in the stitches. However, the values obtained are in line with the requirements for linen fabrics used for clothing. The modification process also lowers the hygroscopicity, air permeability and, in some cases, water absorption as compared with fabrics before the modification.

Key words: *health promoting substances, linen textiles, use properties, biodegradation, resistance to care.*

Introduction

The Institute of Natural Fibres and Medicinal Plants, the Zyrardow branch, responding to the market needs, conducted research on the modification of linen fabrics with preparations containing any of these products: E vitamin, aloe vera, beeswax, extract from natural silk protein, all designed for use in so-called wellness products.

E vitamin is one of the water-indissoluble and fat-soluble vitamins. It is a strong antioxidant which retards the process of aging of the body. From the chemical point of view, it is the $C_{29}H_{50}O_2$ – compound, described as α-Tocopherol. This vitamin has been used in the production of pharmaceuticals and cosmetics for years. In cosmetics it serves as an antioxidant and moisture absorber, thus caring for the skin and enhancing the treatment of various skin diseases. E vitamin is used in cosmetics containing lipids e.g. creams, ointments, emulsions, face and body oils and lipsticks. In the human body E vitamin acts as an important antioxidant i.e. a molecule that neutralizes free radicals, which are metabolites forming during molecular respiration and potentially damaging cell membranes [1, 2, 15, 16].

Natural beeswax is a substance produced by bees. Chemically it is a mixture of organic acids, hydroxyl acids, one or two hydroxyl alcohols, esters and hydrocarbons. It is characterised with antimicrobial, enhancing tissue regeneration, immune-stimulation and a generally positive effect on the whole organism, which is indicated by the general improvement of the physical-mental condition, faster recovery and toning action in elderly people [4].

Aloe vera L. is a tree plant with flesh of high nutritional value, as it is a rich source of proteins in the form of amino acids. Aloe flesh has antifungal properties, especially sought for after antibiotic treatments. It is also used in the treatment of skin diseases as well as in the cleaning, moistening and nourishing of skin [5].

Protein extracted from natural silk i.e. soluble hydrolysate of silk proteins is obtained from *Bombyx mori* silkworms. It exhibits a wide range of molecule mass, starting from free amino acids and finishing with long chain polypeptides, which endows it with both moistening and film-making properties [6].

"Wellness" is a reflection of a new philosophy of life. In the textile industry it refers to the functionality of clothing textiles – they have to be comfortable both for the body and soul [1 - 3, 15].

The application of fully biodegradable linen raw material for fabric production, a material characterised with moisture absorption, air permeability, and the absence of allergenic factors, combined with modification with the use of health promoting substances led to the production of 'wellness' products.

Works on the modification of linen fabrics with health promoting preparations that endow the fabrics with the aforementioned functionalities were carried out with respect to their biodegradation and use properties. The use properties are divided into the following groups:

- properties that determine durability (tensile strength, resistance to tear, abrasion resistance)
- aesthetic properties (fastness to change of colour or whiteness, pilling)
- hygienic properties that determine the comfort of using the clothes.

The use comfort (hygienic properties) comprises three elements: sensory, psychological and physiological . Sensory comfort includes sensations perceived in the direct contact of clothing with the skin. Several properties are listed in this category e.g. smoothness, dryness, roughness etc. Psychological comfort implies feelings linked with current fashion. In numerous cases it is fashion that determines whether the user feels comfortable wearing certain types of clothing. Physiological comfort is linked with the microclimate perceived by the user in the layer beneath clothing, especially during physical effort. The groups of properties that affect physiological comfort are referred to as physiological parameters, including air permeability, hygroscopicity, absorbing capacity (the drop method), water vapour permeability, heat insulation, capacity of accumulating electric charge. The combination of these properties constitutes the feeling of comfort in the user [7 - 10].

Table 1. *Values of parameters required for enriched linen fabrics.*

Parameter		Unit	Value	Test method
Breaking force	warp	daN	≥ 25	PN-EN ISO 13934-1:2002
	weft		≥ 20	
Thread shifting in seam	warp,	mm	≤ 6	PN-EN ISO 13936-2:2005
	weft			

Due to current requirements regarding environment protection, studies on product biodegradation are of high importance. Therefore such tests were conducted on the modified 'wellness' linen fabrics.

The biodegradation of products means the microbiological decomposition of organic compounds by live organisms (bacteria, protozoan, actinobacteria, fungi, algae and worms) to less complex chemical components. It is believed to be an environmentally safe process of utilisation of waste products. The capacity of man-made materials to undergo biodegradation is called biodegradability. The process of microbial decomposition is long-lasting, expressed by the following equation:

$$\text{Polymer} + O_2 \rightarrow C\,O_2 + H_2O + \text{inorganic substances } (HNO_3,\ H_3PO_4 \text{ etc.})$$

The results of the chemical transitions that occur during the biodegradation of textile materials are first of all morphological changes linked with the appearance of the product and loss of mechanical properties i.e. a decrease in the breaking force, elongation and resilience. The most active organism in the decomposition of products are fungi and bacteria, which are present in each natural environment i.e. in the air, water and soil. The following factors have been attributed as affecting the process of biodegradation:

- environment – water or soil, soil is especially good for biodegradation,
- moisture – biodegradation occurs under conditions of high moisture,
- temperature – proper temperature determines the biological activity of live organisms. Most bacteria develops at the temperature of 36 °C. For fungi the optimal temperature is about 30 °C. In natural conditions this process occurs at various temperatures and a decrease in temperature causes a slowing- down of the process, but it does not stop it completely.
- concentration of hydrogen ions – pH of the environment and the product undergoing biodegradation. Fungi develop most rapidly in a slightly acidic environment (pH 5.6 – pH 6.0), while bacteria prefers a neutral or slightly alkali environment (pH 7.0 – pH 8.0),
- light – some microorganisms develop better in darkness while others prefer light,
- oxygen access – biodegradation can occur both in aerobic and anaerobic conditions. Biodegradation in anaerobic conditions proceeds solely as a result of bacterial action, whereas in aerobic conditions it occurs as a result of both bacterial and fungal action [11, 12].

The information gathered in the study on selected use features and biodegradation of the modified fabrics will allow for purposeful application of health promoting products for enriching linen fabrics.

Experimental

Methodology

The following parameters were tested to determining the product durability:

- breaking force (according to PN-EN ISO 13934 -1:2002). The test determines the so-called breaking force measured during the drawing of a sample, at constant velocity, until breaking (with the use of a tensile tester).
- the thread slippage index for stitches according to PN-EN ISO 13936-2:2005.

The thread slippage index for stitches is represented by the size of clearance that forms in the sample in the place where it is sewn with a specified force. It is determined for both threads of warp and weft. Higher values of thread slippage indicate the poorer quality of the clothing product.

There are no standards concerning linen fabrics alternatively enriched with E vitamin, aloe vera, beeswax and silk protein extracts. Therefore evaluation of the modification of these fabrics with the above-mentioned products was based on the comparison of values obtained for them before and after the modification according to the requirements defined in the PN-P-82450-02:1986 standard: Linen and linen-like fabrics for common use. The use requirements for shirt fabrics. When the requirements are fulfilled the-linen fabrics are fully suitable for clothing products with health promoting properties. ***Table 1*** presents the requirements concerning selected parameters included in the aforementioned standard.

The aesthetic value was evaluated by determination of the whiteness degree according to PN-P-04775:1988. It was assumed that the change in the whiteness degree after modification should not exceed 5 %. Above this value, the change is visible with the naked eye (organoleptic test).

The use comfort was determined by testing the sensory and physiological comfort. The first one was determined by evaluation of the handle in the organoleptic test.

The part of the studies concerning physiological comfort focused on the determination of air permeability, hygroscopicity and water drop absorption.

Such a choice of properties was based on the fact that the linen fabrics tested were designed for use in summer clothes.

Air permeability is measured as the velocity of air that passes through the test sample under certain conditions of its surface area, pressure drop and time (according to PN-EN ISO 9237:1998 Standard). High values of air permeability indicate that air passes through the fabric easily. These are the parameters that determine the microclimate below the clothing during its use. Hygienic properties of clothing depend, for example, on the gas transfer from the body to the environment as well as on access to fresh air. The air exchange promotes the transport of excess sweat from the skin during the physical effort of the wearer. Air permeability is also linked to the thermal insulation of the clothing [7].

Hygroscopicity is the water vapour sorption capacity of a textile product for air of 100% relative humidity, expressed in % as the quotient of the remainder of the sample mass stored at a relative air humidity of 100% and the dry mass to the dry mass of the sample (according to Standard PN-P-04635:1980). The human body, especially during intense physi-

cal effort, releases high amounts of heat, which is linked to the release of water vapour from the organism. Under such conditions the body secretes sweat, which evaporates from the skin's surface and, by absorbing the evaporated heat, leads to the lowering of the body's temperature, which is the basis for the physiological mechanism of thermal regulation of the organism. Water vapour released in this process must be transported outside the area adjacent to the skin through the clothing, which occurs by moisture sorption and diffusion through a hydrophilic textile product [8].

The capacity of absorption of a water drop was tested according to the JIS 1090:1990 Standard. This method involves determining the time (in seconds) of complete absorption of a water drop.

The durability of the modification discussed to care was evaluated with an instrumental method i.e. scanning electron microscopy photographs, which allowed for visual verification of the presence of the product applied on the fabric surface. The fabrics were tested with no products applied, with the products applied, and applying after a specific number of care cycles. Additionally the presence of E vitamin on the fabrics was determined with colorimetry according to the CHT method (R. Beitlich GmbH, Tübingen, Germany) by dropping a suitable indicator. Dropping $FeCl_3$ solution on the fabric in the presence of E vitamin causes a reduction in Fe^{3+} ions to Fe^{2+} ions. Subsequently by spraying with 2,2'- dipiridil a complex compound of pink colour is formed. The intensity of its colour depends on the content of iron ions (II). This method is applicable only for white fabrics [1].

The care process involved the laundering of the fabrics and then drying and ironing with an iron at a temperature of 150 °C. Laundering in household conditions was done at 60 °C (according to PN-ISO 105-106 Standard – Test conditions – C1S). The presence of health promoting products on the fabrics was determined after the modification and after 5 and 10 care cycles.

The effect of the modification of linen fabrics on the natural environment was assessed by comparison of the biological degradation of the modified and unmodified fabrics during a biodegradation process that ran for six months accord-

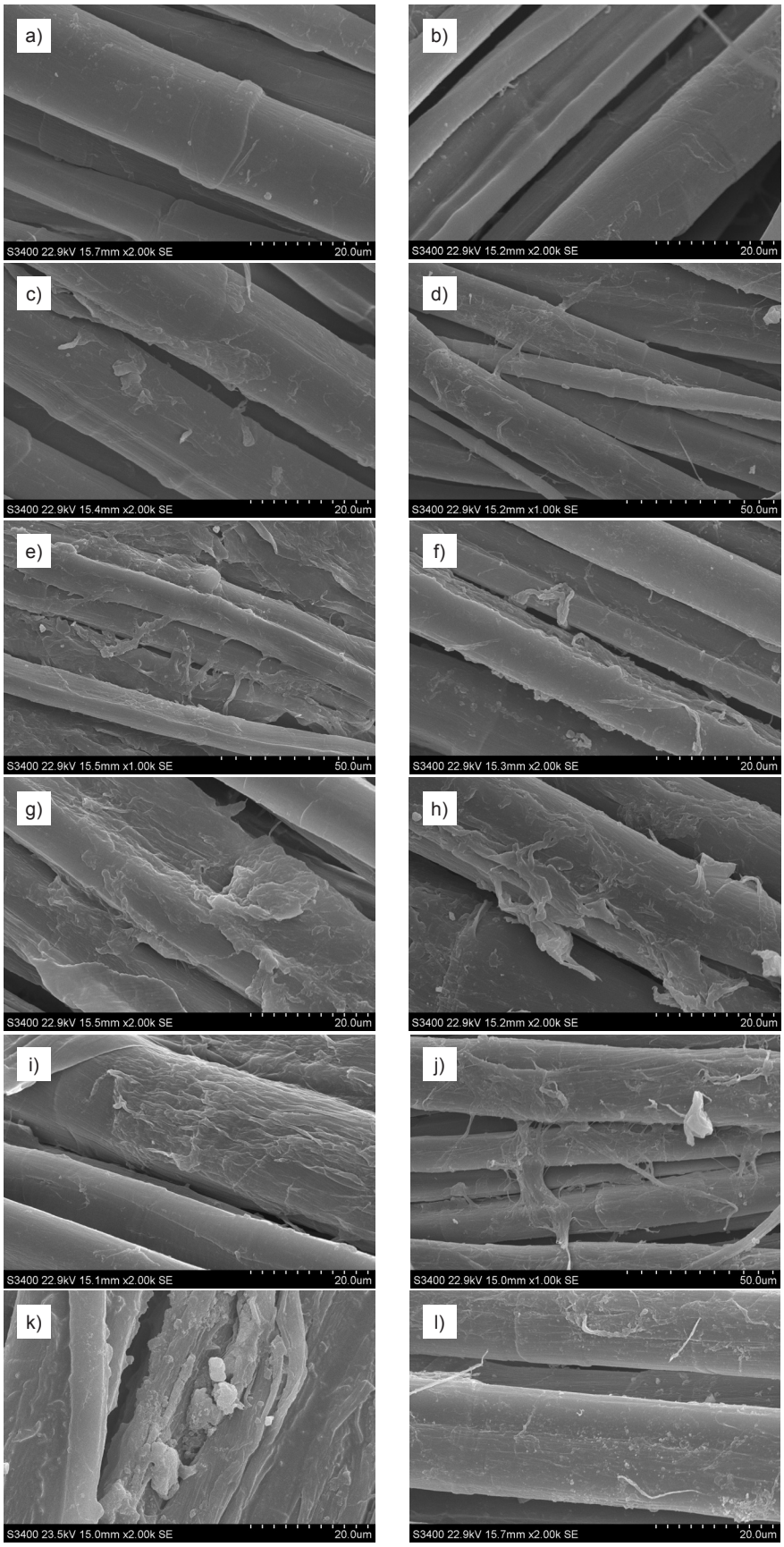

Figure 1. *Microscopic images of the linen fabrics before (a, b); after modification (c, e, g, i, k); after modification and 10 cycles of care processes (d, f, h, j, l). Linen fabrics of surface mass 171 g/m^2 (a, c,d, e, f, g, h, i, j), of surface mass 208 g/m^2 (b, k, l). Modification by combination of condensates of fatty acids, silicones and aloe extract (c, d), amino functional silicon with aloe extracts (e, f), mixture of silicon micro-emulsion and protein from natural silk (g, h), polyethylene emulsion with the addition of natural bees wax (i, j), cyclodextrin complex with vitamin E suspension (k, l).*

Table 2. *Results of the modification of linen fabrics with health promoting substances on selected use properties (durability and aesthetic value).*

Linen fabric - surface mass, g/m²	Type of finished fabric	Type and value of parameter									
		Breaking force, daN		Breaking force decrease (compared to unmodified fabric), %		Thread shifting in seam, mm		Thread shifting in seam change (compared to unmodified fabric), mm		Whitening degree, %	Whitening degree change (percentage points), %
		warp	weft	warp	weft	warp	weft	warp	weft		
171	Before modification	86.3	94.0	-	-	3	3	-	-	68.0	-
	Modified with amino functional silicon with aloe extracts	60.4	65.3	30.0	30.5	6	5	3	2	66.8	1.2
	Modified with a combination of condensates of fatty acids, silicones and aloe extract	71.3	74.5	17.4	20.7	5	4	2	1	67.1	0.9
	Modified with a mixture of silicon micro-emulsion and protein from natural silk	60.5	65.1	30.0	30.7	6	4	3	1	66.5	1.5
	Modified with polyethylene emulsion with addition of natural bee wax	67.5	70.4	21.8	25.1	5	4	2	1	66.8	1.2
208	Before modification	76.2	93.2	-	-	2	2	-	-	55.0	-
	Modified with cyclodextrin complex with vitamin E suspension	60.4	71.0	20.7	23.8	4	4	2	2	54.5	0.5

ing to a method developed by the authors. It was assumed that the modified fabrics are environmentally friendly if their biodegradation is at a similar level as this process for unmodified fabric. The biodegradation degree of the fabrics was measured by determination of the breaking force (according to PN-EN ISO 13934-1:2002) and an organoleptic test of the appearance of the unmodified fabrics, modified fabrics and those samples after 6 months of biodegradation.

Testing equipment

The tests were carried out with the use of the following equipment:

- Whiteness degree and changes therein were tested with a d/8 colorimeter (Spectrocolor)
- The breaking force and thread slippage index in stitches were tested with a Tiratest tension tester.
- Photographs of the fabrics with and without products applied were taken with an S-Hitachi 3400N scanning electron microscope (Japan) in the high vacuum mode (detector of secondary electrons SE). Linen fabrics with and without products applied were initially sprayed with a gold layer. Magnification of 1,000 and 2,000 at a working distance of about 15 mm were set as the optimal for showing the fabric structure and the presence of the products applied. Such parameters allowed for the observation of characteristic features of the fabric surface and elementary fibres [13, 14].
- Air permeability was tested with the use of an Air Permeability Tester III.

Materials

Three types of samples of linen fabrics with a plain weave, bleached (whiteness degree of 68% and 55% according to Stephensen):

- with a mass per square meter of 171 g/m² and 208 g/m² – these samples were used for testing the effect of the modification of health promoting substances on selected use properties of the fabrics and durability of the modification after care processes,
- with a mass per square meter of 208 g/m² and 242 g/m² – these samples were used for testing the effect of the modification on the use comfort of the clothing and natural environment

Application testing

The modification that endowed fabrics with health promoting properties was carried out on a laboratory scale with the use of a Labour-Foulard horizontal padding machine (Werner Mathis AG), and drying and thermofixation was conducted in a laboratory chamber dryer.

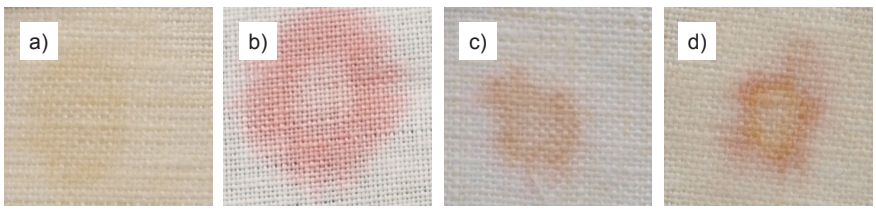

Figure 2. *Images of linen fabric after dropping an indicator of the presence of vitamin E; a) before modification, b) after modification, c) after 5 cycles of care processes, d) after 10 cycles of care processes.*

For the modification of the fabrics the following products were applied alternatively:

- cyclodextrin complex with vitamin E suspension,
- amino functional silicon with aloe extract,
- combination of condensates of fatty acids, silicones and aloe extract,
- mixture of silicon micro-emulsion and protein from natural silk,
- polyethylene emulsion with the addition of natural bees wax.

The compositions of separate finishing baths were compliant with the recommendations of the producers of the modifying products [17].

Results and discussion

Table 2 presents the effects of the modification of linen fabrics with health promoting substances on selected use properties (durability and aesthetic value). Values are provided for unmodified and modified linen fabrics containing vitamin E, aloe extract, beeswax, and silk protein extract, respectively.

Figure 1 shows microscopic images of the fabrics before and after modification and after 10 cycles of care processes.

Figure 2 presents images of linen fabric:

- before modification,
- after modification with a product containing vitamin E,
- after modification with a product containing vitamin E and after 5 cycles of care,
- after modification with a product containing vitamin E and after 10 cycles of care,

Table 3. *Results of the effect of the modification of linen fabrics with health promoting products on the comfort of use (sensory and physiological).*

Linen fabric - surface mass, g/m²	Type of finished fabric	Parameter			
		Hygroscopicity, %	Air permeability, mm/s	Handle	Water absorption speed. Drop method, s
242	Before modification	15.8	355	hard, rough	0
	Modified with amino functional silicon with aloe extracts	14.8	250	soft, slippery	94
	Modified with a combination of condensates of: fatty acids, silicones and aloe extract	15.5	267	soft	0
	Modified with a mixture of silicon micro-emulsion and protein from natural silk	15.0	248	soft, slippery	112
	Modified with polyethylene emulsion with the addition of natural bee wax	15.4	319	soft, smooth	0
208	Before modification	20.2	478	hard, rough	0
	Modified with a cyclodextrin complex with vitamin E suspension	16.9	396	soft, slippery, full	100.8

Table 4. *Test results for biodegradation of fabrics tested.*

Type of finished fabric	Breaking force before biodegradation, daN				Breaking force after six months of biodegradation, daN	Organoleptic determination of biodegradation after six months
	Surface mass linen fabric					
	242 g/m²		208 g/m²		242 g/m², 208 g/m²	242 g/m² , 208 g/m²
	warp	weft	warp	weft		
Before modification	75	66	76	93	Various damage to fabrics (broken threads of warp and weft) and the form of the fabric make it impossible to determine the breaking force according to the valid standard.	During retrieving the fabric from soil the sample breaks easily (disintegrates when touched). After rinsing and drying the fabric is brittle, susceptible to breaking, and its handle is rough and stiff. In one sample there are places with no visible damage (evaluated organoleptically) and places with various damage to the threads of warp and weft. The length of fabrics with no visible damage varies between 1 and 15 cm. There are spots of different colour on the fabric surface – yellow, rusty and russet.
Modified with amino functional silicon with aloe extracts	67	46				
Modified with a combination of condensates of fatty acids, silicones and aloe extract	75	55				
Modified with a mixture of silicon micro-emulsion and protein from natural silk	71	47				
Modified with polyethylene emulsion with the addition of natural bees wax	64	40				
Modified with cyclodextrin complex with vitamin E suspension			60	71		

- after dropping with an indicator of the presence of vitamin E.

Results of the effect of the modification of linen fabrics with health promoting products on the comfort of use (sensory and physiological) are presented in ***Table 3***.

Table 4 shows the results of tests on the effect of the modification on the biodegradation of the fabrics tested.

The results presented in ***Table 2*** allow to conclude that the modification of linen fabrics with health promoting products affects their use properties in the following ways:

- It lowers the breaking force for each variant of the modification, both in the weft and warp, by about 17.4 - 30.7% as compared with unmodified fabrics. However, the value of the breaking force for fabrics after the modification is still higher than the value required according to the standard for linen shirt fabrics.
- It increases the value of the thread slippage index in stitches for each variant of the modification by 1 to 3 mm, which is a property not welcomed by the user. Yet this value is still within the limits accepted by the standard.
- It lowers the whiteness degree for each variant of the modification by no more than 1.5%. Such change is not perceptible in the organoleptic evaluation.

The decrease in the breaking force depends on the chemical base of the product used for the modification. Lower values are obtained when the modification is made with silicon based products. Such products cause a drop in the breaking force by about 20.7 – 30.7% as compared with the fabric before modification. Products based on fatty acids or polyethylene, when used in the same amounts of the modifying product, result in a decrease in the breaking force of about 17.4 - 25.1%. Similarly the thread slippage index in stitches is slightly higher (worse for the user) for the fabrics treated with an agent containing silicon.

The analysis of SEM images of linen fabrics before and after modification and after 10 cycles of care allowed to confirm the following:

- The presence of the health promoting product applied on the fabric surface after application,
- The presence of the health promoting product applied on the fabric surface after application and the following care processes, while the amount of the product is lower than before the care.

The images of linen fabric after dropping the E vitamin indicator, presented in ***Figure 2***, confirm:

- the presence of the product with vitamin E applied on the fabric surface after application,
- the presence of the product with vitamin E applied on the fabric surface after application and after a following 5 and 10 cycles of care, while the amount of the product applied is lower than directly after the application.

The results presented in ***Table 3*** allow to state that the modification of linen fabrics with health promoting products has an ef-

fect on the comfort of use in the following ways:

- It slightly lowers the hygroscopicity of the fabric at a mass per square meter of 242 g/m^2 from 15.8% for the unmodified fabric to 14.8% - 15.5% for the modified fabrics. Higher hygroscopicity was observed for the fabrics modified with products that do not contain silicon compounds, whereas it was lower for modification with silicon containing products. In the case of the fabric with a mass per square meter of 208 g/m^2 modified with a product with vitamin E and functional polysilicons, a decrease in hygroscopicity was observed of 20.2% to 16.9% as compared with the unmodified fabric.
- It lowers the value of air permeability for fabric with a mass per square meter of 242 g/m^2 from 355 mm/s before the modification to values between 248 and 319 mm/s for the modified fabrics. Lower values than these were observed for the modification with products containing silicon based compounds. For the fabrics with a mass per square meter of 208 g/m^2 modified with vitamin E containing an agent and functional polysilicons, the drop in air permeability was smaller (from 478 to 396 mm/s).
- The handle of the modified fabrics is perceived as pleasant depending on the product used, described as soft and slippery or soft and smooth or soft, slippery and full. The unmodified fabric handle is described as rough and hard.
- The water absorption capacity for the fabrics modified with a combination of condensates of fatty acids, silicones and aloe extract and with polyethylene emulsion with the addition of natural beeswax is instant (zero seconds), as in the case of the unmodified fabrics. In the case of modification with products containing silicon based compounds, this parameter is worsened as the value is up to about 100 seconds.

The results presented in ***Table 4*** allow to conclude that biodegradation of the fabric samples tested can be done only by organoleptic evaluation. Biodegradation was uneven over the whole surface of the samples. A similar phenomenon was observed for both unmodified and modified samples. The condition of the fabric after 6 months of biodegradation does not allow for determination of the breaking force according to the PN-EN ISO 13934-1:2002 standard.

Conclusions

- Modification of linen fabrics with health promoting products has an effect on their use features i.e. it reduces the value of the breaking force and worsens the thread slippage index parameter in stitches. However, these values are still within the limits required for linen shirt fabrics according to the standard. The changes in the whiteness degree are not perceptible in the organoleptic test.
- Modification of linen fabrics with health promoting products is resistant to 10 cycles of care processes.
- Modification of linen fabrics with health promoting products affects the comfort of use i.e. improves the handle and worsens the hygroscopicity and air permeability. Water drop absorption is worsened only in the case of using products containing silicon based compounds.
- Modification of linen fabrics with health promoting products does not have an effect on the biodegradation process of the fabrics. Both unmodified and modified fabrics undergo biodegradation in the same way for the same period of time.
- It is important that all health promoting products tested contain e.g. aloe, vitamin E, and beeswax used together with conventional finishing agents such as softeners and reactants. Therefore the discussed effect of the modification on the use properties of linen fabrics and the natural environment applies to all substances present in the modifying complex.

References

1. Zyschka R, Brückmann R, Krammerer B, Schreiber H. Wellness-Finish mit Vitamin E. *Textilveredlung* 2004; 39, 5/6; 10-15
2. Michałowski W. Wellness – finishing of textiles containing E vitamin. *Przegląd Włókienniczy WOS* 2005; 11.
3. Michałowski W. Active textile products. *Przegląd Włókienniczy WOS* 2006; 7.
4. Bornus L. *Beekeeping encyclopaedia*. Warszawa PWRiL 1986
5. www.wikipedia.org/wiki/Aloes
6. www.proteina.com.pl/opis-wlsnosci-kosmetycznych.php
7. Matusiak M. Analysis of chosen physical properties of the light cotton fabrics influencing the physiological comfort of using. *Przegląd Włókienniczy* WOS 2006; 2: 48.
8. Brzeziński S. *Chemical textile processing – selected topics. Part III*. Ed. Technical University Łódź/Bielsko Biała Publishing; 1999; 120.
9. Kowalski K, Wykin-Orlikowska G, Manduk-Chuchla T. Biophysical properties of knitted fabrics in laboratorial research and user tests. In: *5th International Conference Polish knitting in Europe,* Tarnowo Podgórne, 2002.
10. Szosland J. *Basics of fabrics structure and technology*. Ed. Scientifical – Technical Publishing, Warszawa, 1972.
11. Salerno-Kochan R, Szostak-Kotowa J. Factors influencing the microbiological decomposition of textile fabrics. Part I. Influence of environmental factors. *Przegląd Włókienniczy + Technik Włókienniczy* 1998; 8; 22.
12. wikipedia.org/wiki/Biodegradacja
13. Kicińska- Jakubowska A. Kozłowski R, Gieparda W. Techniques for nano-analysis of textile and composites. In: *5th International Conference of Textile Research Division NRC*. Cairo, Egypt, April 6-8, 2008. *Textile Processing: State of the Art & Future Developments* 2008; 5(VI): 306-314.
14. Kicińska-Jakubowska A, Bogacz E, Kozłowski R, Zimniewska M. Electron scanning microscope analysis as a more effective tool for studies on natural fibres. In: *4th Global Workshop of the FAO/ESCORENA European Cooperative Research Network on Flax and other Bast Plants*. Innovative Technologies for Comfort, Arad - Romania, 2007; 07-10 October.
15. Marszałek R, Wacławek M, Sapieja A, Binkowska B, Hernik T, Kicińska-Jakubowska A, Marcinowska B. Enriched linen textiles as a material for wellness products. In: *Organic Chemistry, Biochemistry, Biotechnology and Renewable Resources. Research and Development. Volume 1-Today and Tomorrow*; Ed. Nova Scence Publisher, 2013.
16. Marszałek R, Wacławek M, Binkowska B, Hernik T, Sapieja A, Mackiewicz-Talarczyk M, Kicińska-Jakubowska A. Aloe, bee wax, protein from natura silk as preparations for modification of linen fabrics. *In: 18th International Conference for Renewable Resources and Plant Biotechnology NAROSSA*. Magdeburg, Germany, 2012.
17. Information materials, CHT R. BEITLICH GMBH.

Received 11.07.2013 Reviewed 25.03.2014