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Development and Characterization of Sustainable Coatings as an Ecological Alternative to Textile Treatment

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Abstract: The modification of cellulose woven fabrics and viscose nonwovens was carried out with the aim of preparing sustainable coatings from biodegradable natural polymers. The modification of fabrics with biodegradable natural polymers represents an ecological alternative to other textile modifications such as the sol-gel process. Coatings were prepared from erythritol, gelatin and collagen in various formulations with the addition of propolis and alginate fibers and a natural plasticizer (glycerin). The morphology of the materials was determined before and after modification with Dino-lite, the pH value, the drop test method, the angle recovery angle, the thickness and the mass per unit area. The modifications have no significant effect on the thickness and mass per unit area, in a larger proportion they show hydrophilic properties, which favours the application for medical purposes - for example the absorption of exudates, wound dressings etc. Due to the neutral and slightly alkaline pH value of the modified samples, they are suitable for external application on the skin. The recovery angle of the modified samples proves that the samples do not tend to crease and that they retain their elasticity after modification and have a pleasant textile feel (fabric hand).

Keywords: textiles; modification; sustainable coatings; natural biodegradable polymers; alginate fibers; propolis; wound dressings

1. Introduction

Polymers are ubiquitous advanced materials. They can be found in almost all materials used in everyday life. By definition, polymers are large molecules (macromolecules) formed by bonding (chemically linking) a series of building blocks. The word polymer comes from the Greek and means "many parts". Each of these parts is called a monomer, which means "one part"[1].

There are two types of polymers, depending on their origin: synthetic and natural. Synthetic polymers are obtained from petroleum. Examples of synthetic polymers are fibers, flexible films, adhesives, resistant paints and tough but lightweight solids. Natural polymers are found in nature and can be extracted.

The importance of bio-based polymers lies in the large variety of renewable raw materials and the environmentally friendly prospects of the materials [2]. In view of this, as well as growing environmental awareness and the promotion of sustainable development, the development of new biodegradable and environmentally friendly materials is being encouraged.

For biodegradable polymers, whether synthetic or natural, the focus is on their development, on the development of the biodegradation process, on the modification of the structure and properties of the polymer [3].

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Such biodegradable polymers are often used in the field of environmental protection, in the textile, food, pharmaceutical and cosmetics industries, etc. Natural biodegradable polymers are also characterized by their biocompatibility [4].

Natural polymers are also known as biopolymers and are modified for specific applications or provided with various additives (fillers, dyes, stabilizers). They are biodegradable, i.e. they can be broken down by the action of microorganisms. The speed of biodegradation is influenced by environmental factors and the properties of the individual polymer materials [5].

In order for biopolymers to be used in the food industry as packaging material, in the textile industry with applications in medicine, in cosmetics, etc., the materials must not be toxic, must have suitable processing properties and should preferably be produced from renewable sources. The biopolymers that are suitable for food packaging are also suitable for contact with the skin, wounds, etc. They are listed in Table 1.

Table 1. An overview of biopolymer sources.

Source of Biopolymer	Biopolymer
polysaccharides	agarose [6]
	alginates [7]
	cellulose [8]
	glucomannan [9]
	hemicellulose [10]
	chitosan [11]
	starch [12]
proteins	casein [13]
	collagen [14]
	whey proteins [15]
	soya proteins [16]
	zein [17]
	gelatin [18]
lipids and waxes	vegetable oil and animal fats [19]
	waxes [20]

Among the biopolymers derived from natural sources, polysaccharides attract a lot of attention due to their biomedical and physicochemical properties, such as biodegradability, biocompatibility, non-toxicity, renewability and availability.

Natural macromolecules, e.g. starch, gelatin, collagen, are generally degraded in biological systems by a hydrolysis reaction and subsequent oxidation.

Not surprisingly, most synthetic biodegradable polymers contain hydrolysable bonds along the polymer chain, e.g. amide, enamine, ester, urea and urethane bonds, which can be biodegraded by microorganisms and hydrolytic enzymes.

Since many proteolytic enzymes specifically catalyze the hydrolysis of peptide bonds adjacent to substituents in proteins, substituted polymers containing substituents such as benzyl, hydroxy, carboxy, methyl and phenyl groups have been prepared in the hope that the introduction of these substituents may increase biodegradability [21].

In addition, most enzyme-catalyzed reactions take place in aqueous media, and the hydrophilic/hydrophobic nature of synthetic polymers has a significant impact on biodegradability.

It appears that polymers containing both hydrophilic and hydrophobic segments are more biodegradable than polymers containing either only hydrophilic or only hydrophobic structures [3].

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In view of this, the modification of textiles with biodegradable polymers is certainly an alternative to the usual textile treatments, in particular the sol-gel process [22]. The sol-gel process offers great possibilities in terms of adaptability and the achievement of targeted modifications, albeit through the combination of different inorganic and organic starting materials. The sol-gel process in the narrower sense comprises hydrolysis and condensation reactions of metal alkoxides, whereby a continuous three-dimensional metal oxide network is formed [23].

The sol-gel process, like many other processes in the textile industry, essentially stands for the modification of textiles with synthetic compounds, while the modification of textiles with biopolymers represents a switch to sustainable, biodegradable and natural polymers.

Natural polymers have a much more complex structure than synthetic polymers, which have a relatively simple structure. The basic constitutional units of natural polymers are more complex than of synthetic polymers, which affects the conformation and configuration of the macromolecules.

This complexity of natural polymers offers a number of advantages in the modification of textiles with the aim of obtaining potentially biodegradable medical or cosmetic materials for e.g. wound dressings. The general principle of action of most wound dressings is that they dissolve within 48 hours on an open wound by interacting with microorganisms and other bodies [24]. In this way, they eliminate necrosis and promote the formation of "young skin".

Wound dressings are usually based on synthetic compounds, but they can also be based on bio derivative polymers and hydrogels, namely collagen and alginate.

Collagen belongs to the group of multifunctional proteins most commonly found in bones, skin, tendons and ligaments. The word collagen comes from the Greek word that “kola” means gum and “gen” means producing. Collagen is biodegradable and biocompatible, i.e. it rarely causes immune reactions in the body. It is therefore suitable in biomedicine for the production of implants and in various modifications as a carrier of biomass or as an active ingredient in a drug [25]. It is a component of dental composites, skin regeneration templates and biodegradable matrices. It is used in cardiovascular surgery, plastic surgery, orthopedics, urology, neurology and ophthalmology [26].

Collagen can be extracted from natural animal and plant sources or obtained from recombinant protein production systems using bacteria, yeast, insects or plants, mammalian cells, or artificial fibrils [27]. The most common animal sources of collagen are human collagen, bovine collagen, porcine collagen and fish collagen, with bovine collagen being widely used in collagen-based products.

Alginates belong to the group of polysaccharides with a linear structure that are often used to produce hydrogels, which are widely used in medicine due to their biocompatibility. For the use of alginate hydrogels in medicine, it is necessary to improve the mechanical properties so that covalently cross-linked alginate hydrogels are used instead of ionically cross-linked hydrogels. They are prepared by mixing alginate with suitable biocompatible and biodegradable polymers of natural or artificial origin, whose chains are much more flexible compared to the rigid polysaccharide chains of alginate [28]. Applications include wound closure, the treatment of burns, hemostasis, hernia repair, the repair of bone and cartilage defects as well as various dental applications and guided bone repair.

Wounds colonized with biofilms are one of the greatest challenges in chronic wound care. As wound dressings fulfil the so-called post-turner criteria (monitoring exudate and infection, ensuring adequate moisture and temperature of the wound, appropriate, constant pH in the wound, non-toxic and semi-permeable dressings for gases, etc.), sustainable coatings must first be developed that can be treated medically later if necessary [29].

Every good wound dressing must reduce the biofilm and/or prevent the formation of a new biofilm. The biofilm is a structured community of microbes with genetic diversity and variable gene expression (phenotype) that produces behaviors and defence mechanisms designed to generate unique infections (chronic infections) characterized by high tolerance to antibiotics and biocides while being protected from host immunity [30].

Wound dressings should be used as an aid to support biological wound healing. The correct course of wound healing therefore depends not only on the type of wound and the systemic factors,

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but also on the design of the wound dressing and the material interactions within the wound area. Wound dressings should be designed to support the progression of acute wound healing, prevent the transition from acute to chronic wounds, help wounds to reverse from chronic to acute or enable a combination of these processes [31].

The effectiveness of wound dressings varies as it depends on the type of bacteria forming the biofilm, the amount of organic matrix and the hyper variability of the biofilm as well as the environment. No single dressing is effective against all types of microbes in it. This work is part of an active multimodal approach to solve the above problem using biopolymers and the development of sustainable coatings.

2. Materials and Methods

2.1. Preparation of Materials

2.1.1. Preparation of the Textile Materials

Nonwoven and woven fabrics were used for the medical program (wipes, hygiene and health products, dressings such as gauze, plasters, bandages, wound dressings, etc.). Some basic properties of the samples were defined in accordance with international standards. The composition of the samples was determined according to ISO/TR 11827:2012 and revealed that the fabrics are cotton and the nonwovens are viscose fibers.

The mass per unit area was determined according to ISO 3801 and is 104 g m^{-2} for fabric and 101 g m^{-2} for nonwoven. The thickness was determined according to ISO 5084 and is 0.33 mm for the fabric and 0.34 mm for the nonwoven. The fabric was bleached according to its main use, i.e. as a standardized fabric for hospitals and surgical procedures.

2.1.2. Preparation of Sustainable Coatings

The sustainable coatings were prepared with three natural biodegradable polymers, biopolymers derived directly from biomass (erythritol, gelatin and collagen). Each biopolymer was produced separately with propolis and glycerol and separately with alginate fibers and glycerol (Table 2). Glycerol was used as a plasticizer to prevent denaturation of the chains during the reaction.

Table 2. Properties of the polymers.

Polymer	**Erythritol** $C_4H_{10}O_4$	**Gelatin** $C_6H_{12}O_6$	**Collagen** $C_{57}H_{91}N_{19}O_{16}$	**Glycerol** $C_3H_8O_3$	**Propolis** $C_{17}H_{16}O_4$	**Sodium Alginate Fibres**
Molar mass [g mol^{-1}]	122,12	45,00	1302,5	92,09	281,31	/
CAS number	149-32-6	9000-70-8	9000-70-8	56-81-5	/	/
Note	from corn	100 % beef gelatin	fish collagen	/	propolis extract in aqueous solution with niacin and sage	sodium alginate fibres with sodium and calcium carbonate

In the first step of the treatment with erythritol, a solution of distilled water, erythritol (bio&bio) and propolis (Medex) was prepared. The solution was mixed thoroughly. Then glycerol, $C_3H_8O_3$

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(Gram-Mol), was added dropwise to this solution, increasing the speed of mixing. The process was carried out under constant magnetic stirring until a homogeneous solution was obtained.

In the second step, the 5 x 5 cm^2 samples were coated using the dip coating method on a dip coater at a predetermined drawing speed of 1 mm s^{-1} to obtain a thin coating (Figure 1).

Figure 1. Apparatus for dip coating.

The modified samples were dried at room temperature for 24 hours and then at 40 °C for 60 minutes (Figure 2).

Figure 2. Samples dried at room temperature.

The erythritol solution with alginate fibres (Biofarm) was prepared in the same way as that with propolis, with the difference that sodium alginate fibres (Biofarm) were added instead of propolis.

Gelatine (Nutrimedica) and collagen (Mipama) were prepared separately, as was erythritol, first with propolis and then with alginate fibres.

The second step was the same for all modifications.

A schematic representation of the modifications carried out can be found in Table 3.

Table 3. Schematic representation of the modifications carried out.

Erythritol (1 g) + distilled water mixing on a magnetic stirrer with a triangular magnet ↓		**Gelatin (5 g)** + distilled water mixing on a magnetic stirrer with a triangular magnet ↓		**Collagen (5 g)** + distilled water mixing on a magnetic stirrer with a triangular magnet ↓	
+ propolis 10 ml	**+ alginate 10 ml**	**+ propolis 10 ml**	**+ alginate 10 ml**	**+ propolis 10 ml**	**+ alginate 10 ml**

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+ glycerol 5 ml	**+ glycerol 5 ml**	**+ glycerol 5 ml**	**+ glycerol 5 ml**	**+ glycerol 5 ml**	**+ glycerol 5 ml**
20 ± 2 °C 15 min ↓ The samples were kept at room temperature for 24 h ↓ The samples were fixed at 40 °C for 60 min ↓ Materials morphology with Dino-lite pH of the Water-Extract from Wet Processed Textiles Drop test method Determination of recovery by measuring the recovery angle Determination of thickness and mass per unit area, before and after treatment					

2.2. Determination of the Morphology of the Materials

The surface properties of untreated and treated nonwoven and woven fabrics were determined using the Dino-lite microscopy system. The device used was the Dino-lite Pro AM413T, a digital microscope with a resolution of 1.3 megapixels that can achieve a magnification of up to 200x.

2.3. Activity of Hydrogen Ions

The hydrogen ion activity or pH of the water extract from wet-treated textiles was determined according to AATCC test method 81-1988.

The sample (10 g) was boiled in distilled water (250 ml) for 10 minutes (80 °C). The water extract was cooled to room temperature and the pH was determined using a pH metre according to the manufacturer's instructions.

2.4. Drop Test Method

The drop test method, known as absorbency of bleached textiles, was performed in accordance with AATCC 79-2000 and under standard atmospheric conditions (20 ± 2 °C, 65 ± 4 %).

In this test method, a drop of water is dropped from a height of 1 cm onto the surface of a test sample. The time it takes for the reflection of the water drop to dissipate is measured, and recorded as the wetting time. Five seconds or less is generally considered sufficient absorption capacity.

In addition to the time taken for the droplet to be absorbed, the appearance of the remaining droplet was also evaluated, resulting in an assessment of the uniformity of the hydrophilic property. To facilitate the evaluation of the uniformity of the hydrophilic property, a drop of methylene blue solution can be added.

2.5. Determination of the Crease Recovery Angle

The determination of the crease recovery of horizontally folded samples by measuring the recovery angle was carried out in accordance with EN 22312 and under standard atmospheric conditions (20 ± 2 °C, 65 ± 4 %).

A conditioned rectangular sample of specified dimensions is folded and held folded for a specified time (5 minutes) under a specified load (1.019 kg) using a loading device. The crease load is removed and the sample is allowed to recover for 5 minutes in the crease recovery tester. The crease recovery angle was read on the scale of the tester.

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3. Results and Discussion

The results include the morphology of the materials, the hydrogen ion activity, the hydrophilicity and the wrinkle recovery properties. Table 4 shows the codes of the samples and the polymers used.

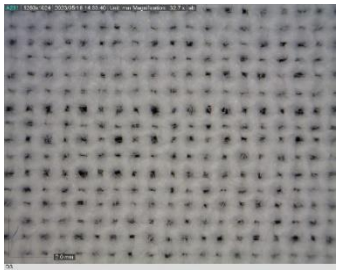
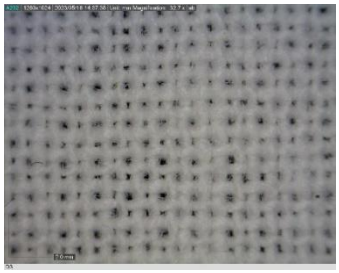
Table 4. Sample code with biopolymers and active compounds.

Code		Biopolymer	Active Compound	Note
Nonwoven fabric	**NN**	/	/	untreated
	NEP	Erythritol	propolis	
	NEA		sodium alginate	
	NGP	Gelatin	propolis	
	NGA		sodium alginate	
	NCP	Collagen	propolis	
	NCA		sodium alginate	
Cotton fabric	**FN**	/	/	untreated
	FEP	Erythritol	propolis	
	FEA		sodium alginate	
	FGP	Gelatin	propolis	
	FGA		sodium alginate	
	FCP	Collagen	propolis	
	FCA		sodium alginate	

3.1. Results of the Morphology of the Materials

The morphology of the coatings, as determined by Dino-lite analysis, is shown in Table 5 to demonstrate the morphological differences between the sustainable coatings produced with three natural biodegradable polymers - erythritol, gelatin and collagen.

Table 5. Morphology of the sustainable coatings.

Code	Morphology of the materials	Code	Morphology of the materials
NN		**FN**	
NEP		**FEP**	

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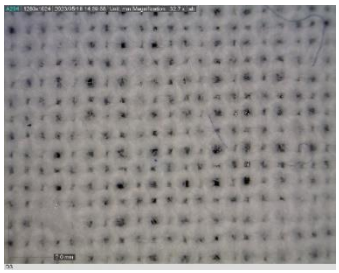
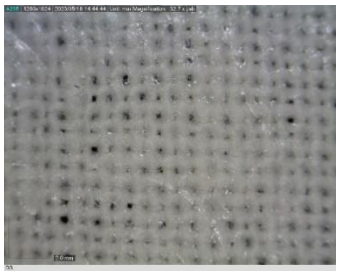
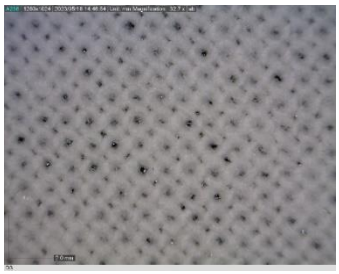
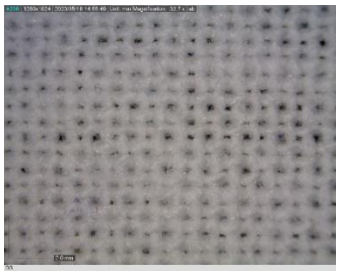
NEA		FEA	
NGP		FGP	
NGA		FGA	
NCP		FCP	
NCA		FCA	

All coatings were clear, transparent and heterogeneous. The coatings were not affected by the incorporation of propolis or alginate fibers, there were no signs of agglomeration, cracking etc. on nonwoven or cotton fabric.

Coatings with gelatin, a non-toxic biomacromolecule of bioactive polypeptides from beef, are assumed to form a gel on a nonwoven fabric. The gels formed by gelatin are naturally transparent, elastic and thermoreversible. A coating prepared with collagen and alginate fibres on a nonwoven fabric exhibits the same behavior.

The morphology of the coatings on the fabric is smooth and homogeneous and the biodegradable polymers - erythritol, gelatin and collagen - have not affected their appearance. The

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morphological properties observed on nonwovens with erythritol (propolis or alginate fibers) show the same behavior as the coatings on the fabrics.

3.2. Results of the Activity of Hydrogen Ions

The effect of the coatings on the pH value is shown in Table 6.

All coatings on cotton fabrics have a neutral pH value (7). Nonwoven fabric has a neutral pH value (7) for all coatings except for coatings with alginate fibres.

Coatings with alginate fibres have a pH value of 8, like seawater. Seawater is a weakly alkaline solution with a pH close to 8.0, close enough to neutral pH that marine organisms adapted to this salty environment can thrive in it.

It is assumed that the commercial alginate fibres used in this work were obtained from brown algae (Phaeophyceae) such as Laminaria hyperborea, Laminaria digitata, Laminaria japonica etc. by treatment with aqueous alkaline solutions, typically with NaOH, which affects the pH of the alginate fibres used.

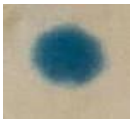
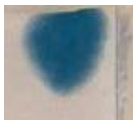
Table 6. Results of the pH value.

Code	pH	Code	pH
NN	7	**FN**	7
NEP	7	**FEP**	7
NEA	8	**FEA**	7
NGP	7	**FGP**	7
NGA	8	**FGA**	7
NCP	7	**FCP**	7
NCA	8	**FCA**	7

3.3. Results of the Drop Test Method

The results of the absorption test with drops (methylene blue) can be found in Table 7. The table shows the test results of cotton and nonwovens. Untreated samples and samples treated with erythritol, gelatin and collagen in combination with propolis and alginate fibers are tested to determine the properties of hydrophilicity and hydrophobicity.

Table 7. Results of the drop test method.

Code	Time	A Drop of Methylene Blue Solution	Code	Time	A Drop of Methylene Blue Solution
NN	1 s 6 cs		**FN**	3 s 8 cs	
NEP	1 s 7 cs		**FEP**	4 s 1 cs	
NEA	1 s 0 cs		**FEA**	4 s 3 cs	
NGP	7 s 1 cs		**FGP**	5 s 1 cs	

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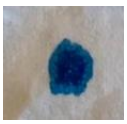
NGA	9 s 3 cs		**FGA**	12 s 0 cs	
NCP	0 s 9 cs		**FCP**	5 s 0 cs	
NCA	0 s 8 cs		**FCA**	3 s 9 cs	

Where is: s – a second, cs - hundredth of a second.

The main objective of this test was to visually determine the absorption and dispersion of methylene blue on cotton fabrics and nonwoven samples.

The results depend on the type of modification and on the sample itself.

Table 7 shows that the drop is evenly distributed in most samples, except for FEA, FGP and FGA. A regular circular shape of the droplet was observed for all samples, except for the samples mentioned, where a longer absorption time of the droplet was measured.

The results of the absorption time are inconsistent. FN has the shortest absorption time with 3 s 8 cs and FGA the longest with 12 s 0 cs. From the results it can be concluded that FN has the best hydrophilicity results. The table shows that not a single sample has a regular circular droplet shape, so that all droplets are unevenly distributed. The absorption time results are also inconsistent. The shortest absorption time is found for the NCA sample and is 0 s 8 cs, the longest for the NGA sample is 9 s 3 cs. From the results, it can be concluded that NCA has the best hydrophilicity.

Table 7 shows that the nonwoven sample is more hydrophilic. It can also be seen that both samples treated with gelatin and alginate fibers have the longest absorption time.

3.4. Results of the Crease Recovery Angle

Table 8 shows the results of the determination of the recovery angles for the nonwovens and Table 9 for the fabric.

Table 8. Results of the angle of recovery of nonwoven textile.

The Angle of Recovery								
Code / Direction of Production	**Machine Direction (°)**				**Cross Machine Direction (°)**			
	1.	**2.**	**3.**	**X (°)**	**1.**	**2.**	**3.**	**X (°)**
NN	101	94	98	**97,7**	107	96	93	**98,7**
NEP	93	98	94	**95**	91	94	97	**94**
NEA	65	74	79	**72,7**	87	84	91	**87,4**
NGP	92	96	98	**95,4**	94	98	101	**97,7**
NGA	91	89	94	**91,4**	93	98	90	**93,7**
NCP	94	89	90	**91**	98	102	107	**102,4**
NCA	93	103	98	**98**	110	114	105	**109,7**

Where X is arithmetic mean.

Table 8 shows that the recovery angles for nonwovens are evenly distributed, both in the machine direction and cross machine direction.

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The smallest recovery angle in the machine direction and cross machine direction was found for the sample NEA, 72.7° in the machine direction and 87.4° in the cross machine direction. NCA has the highest recovery angle in both directions. It is 98° in the machine direction and 109.7° in the cross machine.

It can be concluded that the recovery angle results were influenced by the treatment with different biopolymers. The cotton fabric and nonwoven samples treated with erythritol have the smallest recovery angles.

Table 9. Results of the angle of recovery of fabric.

The Angle of Recovery								
Code / Direction of Production	**Warp (°)**				**Weft (°)**			
	1.	**2.**	**3.**	**X (°)**	**1.**	**2.**	**3.**	**X (°)**
FN	79	90	71	**80**	86	77	90	**84,4**
FEP	59	69	69	**65,6**	82	84	90	**85,4**
FEA	55	59	53	**55,6**	63	61	62	**62**
FGP	69	64	67	**66,7**	73	75	76	**74,7**
FGA	51	56	60	**55,7**	74	71	69	**71,4**
FCP	75	71	73	**73**	69	86	84	**79,7**
FCA	63	62	69	**64,7**	74	72	76	**74**

Where X is arithmetic mean.

Table 9 shows that the recovery angles for all cotton fabric coatings are larger in the direction of the weft.

The FEA pattern has the smallest recovery angle in the direction of the warp and is 55.6 °, in the direction of the weft and 62 °.

The largest recovery angle is FN in the direction of the warp and is 80°, and in the direction of the weft FEP is 85.4°.

3.5. Results of the Ddetermination of Thickness and Mass per Unit Area

The influence of the coating on the thickness of the sample is shown in Tables 10 and 11.

Table 10. Results of the thickness of nonwoven textile.

Code /n	**1**	**2**	**3**	**x**	**σ**	**V [%]**
NN	0,34	0,34	0,34	**0,34**	0	0
NEP	0,34	0,34	0,34	**0,34**	0	0
NEA	0,34	0,34	0,34	**0,34**	0	0
NGP	0,22	0,25	0,22	**0,23**	0,0141	6,13
NGA	0,34	0,24	0,20	**0,26**	0,0589	22,65
NCP	0,29	0,24	0,30	**0,27**	0,0262	9,70
NCA	0,31	0,29	0,30	**0,30**	0,0082	2,74

Where X is arithmetic mean, σ is standard deviation, V coefficient of variation.

Table 11. Results of the thickness of fabric.

Code / n	**1**	**2**	**3**	**x**	**σ**	**V [%]**
FN	0,33	0,33	0,33	**0,33**	0	0
FEP	0,33	0,32	0,31	**0,32**	0,0082	2,56

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FEA	0,34	0,34	0,33	**0,34**	0,0047	1,38
FGP	0,33	0,32	0,32	**0,32**	0,0047	1,47
FGA	0,31	0,31	0,32	**0,32**	0,0047	1,47
FCP	0,32	0,32	0,32	**0,32**	0	0
FCA	0,33	0,33	0,34	**0,33**	0,0047	1,43

Where X is arithmetic mean, σ is standard deviation, V coefficient of variation.

The coatings with erythritol, gelatin and collagen have no significant effect on the thickness of the fabric, but the treatments with gelatin (0.23 mm and 0.26 mm) and collagen (0.27 mm and 0.30 mm) have a smaller effect on the thickness of the nonwoven fabric sample than the initial sample (0.34 mm).

From the results, it was concluded that the samples have uniform thickness without excessive thin and thick spots, nodules and admixtures as factors affecting the thickness of the fabric. In addition, the biopolymer coating is evenly distributed on all samples.

Table 12 shows that the smallest surface mass of the cotton fabric in the untreated sample, i.e. FN, is 39.15 g m^{-2}, and the largest in the sample treated with gelatin and propolis, i.e. FGP, is 47.87 g m^{-2}.

Table 12. Results of the mass per unit area.

Code	Mass per Unit Area (g m^{-2})	Code	Mass per Unit Area (g m^{-2})
FN	39,15	**NN**	11,7
FEP	45,96	**NEP**	18,27
FEA	44,96	**NEA**	15,64
FGP	47,87	**NGP**	20,66
FGA	47,21	**NGA**	26,37
FCP	45,22	**NCP**	21,08
FCA	46,73	**NCA**	24,16

For the nonwoven samples, the smallest surface mass is also for the untreated sample, i.e. NN, and is 11.7 g m^{-2} and the largest in the sample treated with gelatin and alginate fibers, i.e. NGA, at 26.37 g m^{-2}.

All processed samples showed an increase in surface mass after modification of the samples, both for woven and nonwoven fabrics.

The gelatin-treated samples have the highest surface mass (fabrics and nonwovens) and the erythritol-treated samples have the lowest (fabrics and nonwovens), although this is greater than the surface mass of the untreated samples. This can be explained by the specific density of the active ingredients used for the modification.

4. Conclusions

A study of the scientific and technical literature leads to the conclusion that sustainable coatings with biopolymers on textiles are a topical issue.

Nonwovens are suitable for wound dressings due to their properties, as they are lightweight and have suitable properties for wound care such as absorbency, softness and elasticity.

There is currently no dressing that is suitable for all wound types. As the healing of a wound progresses and the amount of exudate decreases, a single dressing is not optimal for the different phases of healing. For one phase of healing, alginate dressings and propolis dressings have great potential to optimize the microenvironment of the wound.

It can be concluded that after the modification of the cotton fabric and the nonwoven fabric no significant changes in the basic technical properties (thickness, mass per unit area) compared to the untreated samples can be observed. A larger proportion of samples exhibit hydrophilic properties, which favours their use for medical purposes - for example, the absorption of exudates.

Samples with better hydrophilic/hydrophobic properties can be refined by adjusting the formulation parameters. Due to the neutral and slightly alkaline pH value of the processed samples, they are suitable for external application on the skin. The recovery angle of the processed samples proves that the samples do not tend to wrinkle and that they retain their elasticity even after modification and have a pleasant textile feel (hand value).

Based on the results obtained, it can be concluded that it would be good to find an optimal formulation for the samples treated with erythritol in combination with propolis and alginate fibers in order to improve the properties of fabrics and nonwovens through the Design of Experiments (DOE).

The development and characterization of biopolymer coatings on medical textiles with different biopolymers using the immersion process represents progress in both theoretical and applied terms. The use of biopolymers with the addition of propolis and alginate fibers enables the production of (medical) textiles with unique properties and represents a promising modification of textiles with sustainable coatings.

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