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ANNALS OF THE UNIVERSITY OF ORADEA
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EVALUATION OF THE PERFORMANCE PROPERTIES OF FABRICS CONTAINING RECYCLED COTTON FIBRE

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Abstract: *Recycling and reusing of textile waste as a resource can be an important opportunity to reduce environmental pollution and make a great contribution to sustainable development of society. Recycling cotton waste makes it low-priced and high return value. This way it can be easily industrialized and commercialized to extend the life cycle of cellulose resources. The aim of this research was to investigate the performance properties of fabrics made from recycled cotton and virgin polyester blends. The fabrics were knitted using different knitting constructions while keeping the yarn count and fabric content constant. The study focused on evaluating the pilling and elasticity properties of the fabrics and the effect of knit structure on these properties. Especially pilling is one of the performance characteristics that fabric manufacturers receive feedback from their customers and as it is stated in the literature, it should be improved. The results showed that knitting type had a significant impact on pilling and elasticity values. It was observed that the napping process negatively affected the pilling property as it caused mechanical deformation in the fabric. The findings of this research can help manufacturers and designers to select the appropriate knitting construction to achieve the desired performance properties in fabrics made from recycled cotton and virgin polyester blends. This research contributes to the ongoing efforts to promote sustainable practices in the textile industry.*

Key words: *Recycled cotton, pilling, elasticity, recycling, sustainability.*

1. INTRODUCTION

Worldwide production of fibre closely reflecting the consumption of textile products has nearly doubled in the last 20 years. Increasing from 58 million tonnes in 2000 to 109 million tonnes in 2020, it is estimated to increase another 34% in the next 10 years [1,2]. Cotton was the second most-produced fibre with a 23% share in worldwide fibre production in 2019 [3]. Intensive pesticide, fertilizer and water use, social problems in cotton planting and harvesting have a significant share in textile-related environmental problems [4]. Therefore, recycling cotton waste at all phases from harvest to usage can significantly decrease the cotton environmental burden by eliminating agricultural effects [4]. In cotton-containing waste products, due to dyeing and blending, sorting and separation are difficult and therefore the quality of the recycled products is not stable. An effective way of recycling post-consumer waste cotton is needed to produce higher quality and higher value-added products, decrease waste cotton production, and eliminate the environmental impacts of landfilling and incineration. Moreover, recycled cotton has a high potential and it is also a sufficient starting material for the recycled cotton industry.

However, recycling cotton waste is often problematic because cotton textiles are mixed with other natural and chemical fibres and textile dyes. Furthermore, the cotton waste materials are not proper for garment manufacturing because of the lower quality of recycled fibres. Current recycling methods of cotton waste consist of mechanical, chemical and biological recycling. The mechanical recycling method includes short technological processes and is low-cost [5].

Textile products are generally produced as blends to increase performance, quality features, durability and hand value and to achieve cost savings. Polyester fibre provides better performance in combination with any type of yarn due to its higher strength, resiliency, resistance to most chemicals, quick-drying, wrinkle resistance and easy care properties [6]. Since recycled cotton fibres have a short structure, mixing these fibres with polyester fibres adds strength to the yarn and facilitates spinning. In addition, fibre flys during knitting or weaving can be reduced by blending recycled cotton fibres with polyester fibres [7]. The fabric structures in which recycled cotton and virgin pes are used together do not meet the quality expectations for products with higher added value. There are some problems regarding the elasticity properties and surface unevenness of the fabrics. The pilling problem observed in fabrics is one of them. The most important fabric feature affecting pilling properties is fabric structure (knitted or woven), fabric texture or weave type, fabric density and fabric weight.

In this research, recycled Cotton - virgin PES blended fabrics with different knit structures at the same yarn count were determined. Elasticity and pilling properties, which are expected to be developed in recycled fabrics, were taken into consideration and tests were carried out. This research contributes to the field, as these properties significantly affect the acceptability and long-term use of the fabric for clothing.

2. EXPERIMENTAL

2.1 Materials

In the scope of the research, the commonly used fabric weave types were chosen as main parameter and 5 fabric constructions were evaluated. As seen in Table 1, all fabrics were knitted using 20/1 Ne yarns containing 70% r-Co and 30% v-PES. Since the yarns get thicker with the increase in the recycled cotton content due to the shorter fibre length, 20/1 Ne yarn count was chosen in this study which also commonly preferred for sweatshirt production. The cotton fibre was recycled from fabric scraps which are pre-consumer wastes. In this type of recycling, the collected scraps are sorted out according to their colour as well as their colour tone. Afterwards, the cotton scraps are turned into fibre by a textile shredding machine (Figure 1). The cotton bales are blended with virgin polyester in the blow room to achieve the quality of the rotor spinning process due to the shorter fibre length of recycled cotton. For this research, the yarns were knitted in five different constructions as presented in Table 1 in the original colours of recycled cotton. After the knitting process, the fixation was performed on all fabrics by the stenter machine. No chemical treatment was performed from defibering to knitting making cotton recycling more sustainable.

Fig. 1: The textile shredding machine (left) and defibred cotton (right)

The fabric constructions were determined for sweatshirt production for the winter season considering the aim of the research.

Table 1: The fabric properties

Fabric Code	Yarn Count (Ne)	Fabric Composition	Fabric Construction	Post-treatment
F1	20/1	70% r-Co 30% v-PES	2x2 Rib	-
F2	20/1	70% r-Co 30% v-PES	Three-thread fleece	Napping
F3	20/1	70% r-Co 30% v-PES	Single jersey	-
F4	20/1	70% r-Co 30% v-PES	Two-thread fleece	-
F5	20/1	70% r-Co 30% v-PES	Pique	-

2.2 Methods

The performance properties of fabrics were evaluated regarding the use of a sweatshirt as a winter garment. Therefore, the related tests presented in Table 2 were performed.

Table 2: Fabric tests, testing instruments and used standards

Fabric Tests	Testing Instrument	Test Standard
Mass Per Unit Area	Sartorius Scales	EN 12127
Thickness	SDL Atlas	ISO 5084
Elasticity	Zwick Z010 (Roell)	ISO 20932-1
Pilling	Martindale Tester	ISO 12945-2

For good elasticity, the fabric tends to regain its original size and shape soon after the force causing the deformation is removed [9]. Therefore, recovery becomes possibly the most important factor for the performance characteristics of a sweatshirt as the elbow joint undergoes regular exposure to movement. During the elasticity tests, the distance between clamps was arranged to 100 mm and the applied force was set as 35 N. Five repetitions were generated in a row and the average value was taken as the elongation in per cent. All fabrics were tested both in length and width wises. The equation used for the elongation values is presented in Eq. 1 [9, 10]. To measure the unrecovered elongation values, the reference length was marked as 50 mm distance on the testing specimen before the elasticity test and 30 minutes after the test, the marked distance was re-measured. Eq. 2 was used for calculating the unrecovered elongation [10].

$$Elongation\ (\%) = S = \frac{E-L}{L}\ x\ 100 \qquad \textbf{(1)}$$

(S = Elongation in percentage; E = The extended length of the specimen, L = The initial length of the specimen)

$$Unrecovered\ Elongation\ (\%) = C = \frac{Q-P}{P}\ x\ 100 \qquad \textbf{(2)}$$

(C = Unrecovered elongation of the specimen; P = The initial distance marked on the specimen before the elasticity test)

For the statistical analyses, IBM SPSS 20 program was used in the study. Determination of the effects of abric type on the elongation parameters were tested using One-way ANOVA tests with the significance level of α=0.05.

3. RESULTS AND DISCUSSION

The mass per unit area, fabric thickness and pilling test results obtained are presented in Table 3. As expected, the 2x2 Rib (F1) and fleece fabrics (F2 and F4) had greater mass per unit area values due to the knit structure. Additionally, F2-coded fabric had the greatest fabric thickness as a result of the napping process.

Table 3: The results of mass per unit area, fabric thickness and pilling tests

Fabric Code	Mass per Unit Area (g/m2)	Fabric Thickness (mm)	Pilling Grade
F1	330.3	0.47	3
F2	325.2	0.58	2
F3	158.4	0.21	3
F4	266.7	0.39	3-4
F5	188.5	0.28	2-3

In this research, since the yarn count was kept constant, the effect of knitting structure on pilling was examined. F2-coded Three-thread Fleece fabric had the worst pilling grade (Figure 2). The one that gives the best pilling grade result is the F4-coded Two-thread Fleece fabric. These two fabric structures (F2 and F4) have similar front-face surfaces, but it is thought that the napping process applied to the F2 fabric on the back face has a negative effect on the pilling property of the front face of the fabric. As stated in the literature, knit construction has a significant effect on the pilling property. It was found that Rib and single jersey fabrics have similar pilling grades [11]. In support of this, 2x2 Rib and single jersey fabrics had the same pilling grade the pique fabric was found to have a similar pilling grade with these two fabrics. In the structure of the pique fabric, the tuck stitches towards the fabric surface generate the three dimensions causing pilling formation on the surface [12].

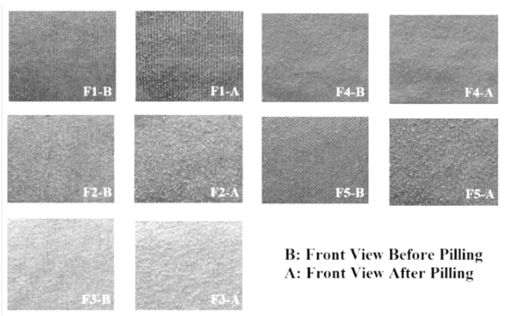

Fig. 2: Front view of fabrics before and after pilling tests

The elasticity values of fabrics were given in Table 4. Regarding data obtained, the fabric knit construction had a significant effect on the elasticity values of the fabrics both wale-wise (p= 0,00) and course-wise (p= 0,00). The elongation values wale-wise of 2x2 Rib fabric (F1) and single jersey fabric (F3) were found to be very close to each other as well as the highest values. These values support the statement that the longitudinal elongation of rib knits is limited and close to the longitudinal elongation of a single jersey [13]. As expected, 2x2 Rib fabric (F1) was found to have a very high elongation value course-wise compared to other fabrics due to the effect of knit structure. The elongation values of Two-thread fleece fabric (F4) were found to be the lowest, followed by Three-thread fleece fabric (F2). The fabric in the pique knit structure had a higher elongation value in the course direction.

When the unrecovered elongation values of these fabrics were examined, two-thread fleece fabric (F4), which had the lowest elongation value, had as well the lowest permanent elongation value as expected (Table 4).

Table 4: The fabric elongation and unrecovered elongation test results

Fabric Code	Elongation (%)		Unrecovered Elongation (%)	
	Wale-wise	Course-wise	Wale-wise	Course-wise
F1	43.94	309.59	9	41
F2	18.67	56.54	3	11
F3	43.92	69.23	9	13
F4	14.42	27.01	3	7
F5	32.32	98.29	5	31

Figure 3 gives unrecovered elongation values versus fabric thickness values for each fabric structure. As supporting the research conducted by Kawasaki and Ono (1968), the elasticity properties of knitted fabrics depend mostly upon the knit construction more than fabric mass per unit area and fabric thickness. This statement was supported in this research by performed statistical analyses; in which the statistically significant effect of fabric construction was found on fabric unrecovered elongation values fabrics in both wale-wise (p= 0,00) and course-wise (p= 0,00) [14].

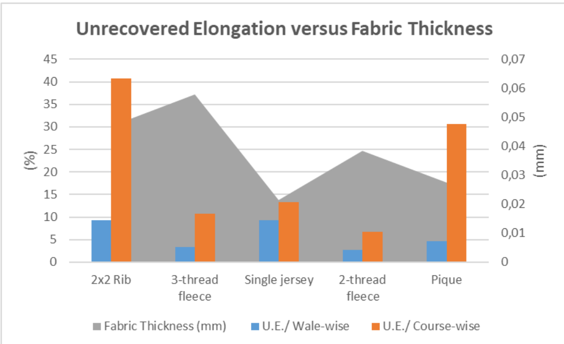

Fig. 3: Unrecovered elongation values versus fabric thickness values

4. CONCLUSIONS

In this research, performance properties of recycled cotton and virgin polyester blended fabrics were investigated. Fabrics were knitted in different knitting constructions by keeping the yarn count and the fabric content constant. The pilling and elasticity performances of these fabrics were evaluated and the effect of knit structure on these properties was investigated.

According to the results obtained, it was seen that knitting type had a significant effect on pilling and elasticity values. In addition, since the napping process causes mechanical deformation in the fabric, it was observed that it affects the pilling property negatively. Moreover, fabric elasticity is better to be judged by observing the knit construction other than the fabric thickness and mass per unit area values.

The study highlights the importance of expanding the use of recycled cotton in value-added products instead of conventional cotton. Additional research is needed to evaluate and develop fabric properties in order to achieve this goal.

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ANNALS OF THE UNIVERSITY OF ORADEA
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STATISTICAL ANALYSIS OF THE PARAMETERS FOR TEXTILE MATERIALS USED FOR SENSORS

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Abstract: *This paper presents aspects regarding the analysis of the independent parameters of the surface electrical resistance for a series of textile samples made by successive knife coating procedures with conductive paste-based metal microparticles, respectively ultrasound-assisted coating using dispersions based on metal microparticles (Cu, Ni, Al, Zn and Ag). The statistical analysis aims to determine the correlations between the vectors of the independent variables (mass, air permeability and thickness of the conductive textile material) and the dependent variable (surface electrical resistance). These samples are prepared for sensor electrodes and must have a low electrical surface resistance.*

Keywords: *textile, sensors, multivariate, electrical resistance, conductive materials*

1. INTRODUCTION

Electrical conductivity is crucial for intelligent textiles to ensure certain electrode functionalities for sensors or electromagnetic shielding. There are methods based on studies regarding the development of conductive materials of poly (3,4-ethylene dioxythiophene)-poly (styrene sulfonate) (PEDOT: PSS) using binders that help to change the viscosity of the electroconductive paste so that it can use different coating methods (knife coating, pad coating and screen printing) [1, 2]. Using the technique 'knife coating' (Doctor Blade Coating), it was found that new properties can be obtained for different textile substrates effectively by integrating various compounds in coating pastes such as graphene nano pellets (GNP), thus providing electrical and thermal conductivity to the fabrics, which can later be used for the development of sensors or thermoelectric resistors for integration into textile articles [3, 4]. In addition, the conductive textiles can also be obtained using electrically conductive paste coatings based on carbon nanotubes (CNT) in water-based polyacrylate dispersions applied to textile materials (fabrics or knits) without polyester or cotton using direct printing, by transfer and screen printing [5, 6]. At the same time, conductive polymers (polyaniline, polythiophene and polypyrrole) based on acrylic binder can be used and deposited on polyester fabrics to obtain conductive textiles [7-12].

2. EXPERIMENTAL PART

In Table 1 are presented samples obtained through knife coating (samples P1, P3, P5, P7, P9, P11, P13, P15, P17) and ultrasound-assisted coating (samples P2, P4, P6, P8, P10, P12, P14, P16, P18) and values for electrical and physical and mechanical parameters obtained after testing in the laboratory (surface resistance (Rs), mass (M), air permeability (Pa) and thickness (δ)).

Table 1: Conductive textile – electrical and physical-mechanical tests

Samples	Ag	Fe_3O_4	Zn	Cu	Al	Rs [Ω]	Physical-mechanical properties		
							M [g/m²]	δ[mm]	Pa [l/m2/sec]
P1	-	-	-	-	-	10^3	580,8	1,28	56,36
P2	-	-	-	x	-	10^6	672,4	1,28	36,62
P3	-	-	-	x	-	10^{10}	572	1,14	43,50
P4	x	-	-	-	-	10^9	635,2	1,268	35,94
P5	-	-	-	-	x	10^5	557,2	1,37	110,6
P6	-	x	-	-	-	10^9	619.2	1,284	35,94
P7	-	-	-	x	-	10^7	570,8	1,13	42
P8	-	-	-	-	-	10^3	672,4	1,27	24.86
P9	-	-	-	-	x	10^5	577,2	1,25	88,14
P10	-	-	-	-	-	10^3	616,8	1,458	47,78
P11	-	-	-	-	-	10^3	567,2	1,458	39,76
P12	-	-	-	-	x	10^3	634,8	1,766	17,82
P13	-	-	-	x	-	10^8	572,8	1,814	30,52
P14	-	-	-	-	x	10^6	648,8	1,76	8,456
P15	-	-	x	-	-	10^5	559,2	1,684	16,2
P16	-	-	-	-	-	10^7	641,6	1,556	5,436
P17	-	-	-	-	x	10^8	551,2	1,646	30,24
P18	-	-	-	x	-	10^7	815,6	1,852	24,88

3. DISCUSSIONS

In order to evaluate the relationships between electrical parameters (Rs) and physico-mechanical parameters have been calculated the correlation coefficient between surface resistance (Rs) and mass (M), air permeability (Pa), and respective thickness (δ). Table 2 are presented the correlation coefficient obtained. Figure 1 is represented the scatterplot matrix of the independent variables (M, Pa, δ) and dependent variables (Rs). Figures 2-4 present the 3D representation of the Rs depending on air permeability, thickness and mass.

The correlation coefficients values from Table 2 show that the correlation coefficients $r_{Rs,\delta}$ = -0.3639, $r_{Rs,M}$ = -0.1599, $r_{\delta,Pa}$ = -0.4889 has negative values, which means that between surface resistance and thickness, respective mass it is an inverse correlation. The increase of the surface resistance values occurs on the quantity of the conductive paste is low and the thickness of the conductive coating is minimal. At the same time, it can be observed that the coefficients $r_{Rs,Pa}$ = 0.0398, $r_{\delta,M}$ = 0.3029, have positive values and this means that between surface resistance and air permeability, it is a direct correlation. As a consequence, woven structure with a high value for Pa will also have a maximal value for surface resistance.

Table 2: Correlation matrix

	Rs	M	δ	Pa
Rs	1	-0.1599	-0.3639	0.0398
M	-0.1599	1	0.3029	-0.3838
δ	-0.3639	0.3029	1	-0.4889
Pa	0.0398	-0.3838	-0.4889	1

In Table 3 is presented the correlation matrix for samples obtained through knife coating, and in Table 4 is presented the correlation matrix for samples obtained by ultrasound -assisted deposition.

Table 3: Correlation matrix

	Rs	M	δ	Pa
Rs	1	0.1643	-0.4146	-0.0963
M	0.1643	1	0.3029	0.1167
δ	-0.4146	0.3029	1	-0.4634
Pa	-0.0963	0.1167	-0.4634	1

Table4: Correlation matrix

	Rs	M	δ	Pa
Rs	1	-0.3172	-0.5197	0.3804
M	-0.3172	1	0.4653	-0.1276
δ	-0.5197	0.4653	1	-0.5770
Pa	0.3804	-0.1276	-0.5770	1

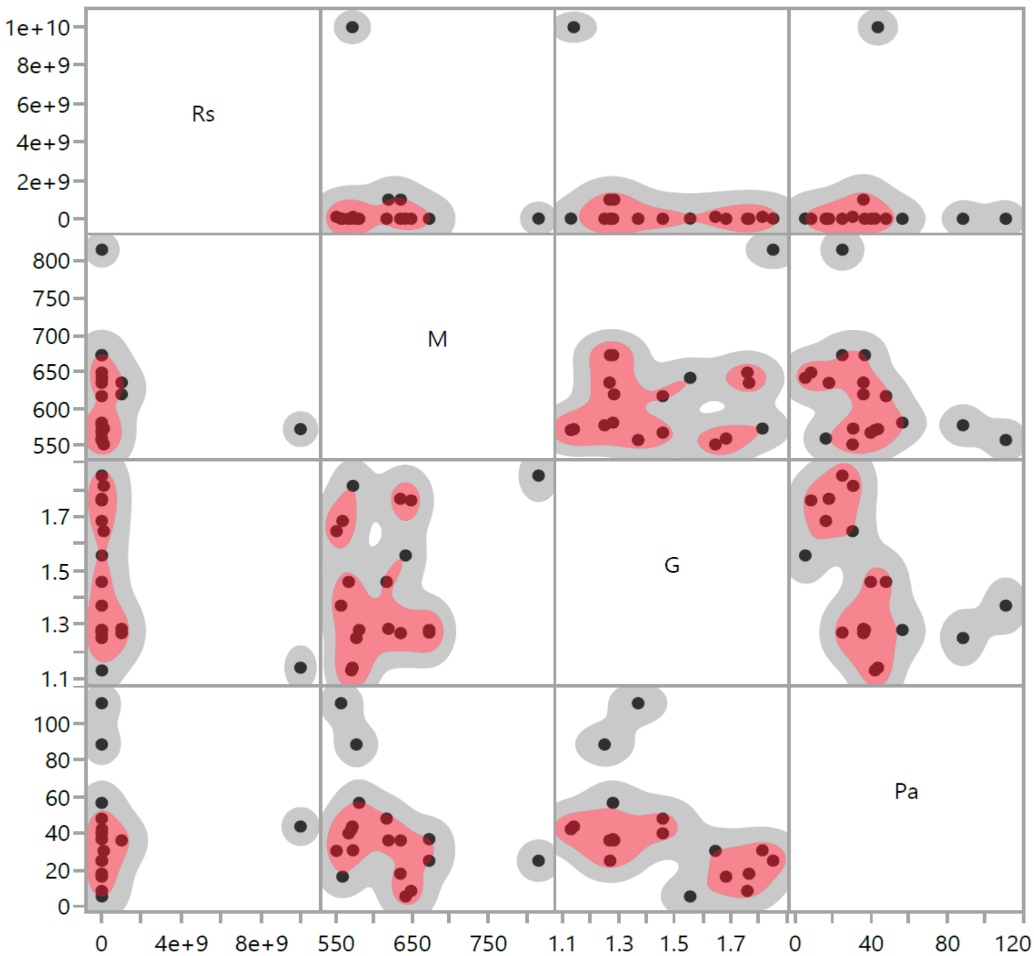

Fig. 1: Scatterplot Matrix-based independent/depend variables

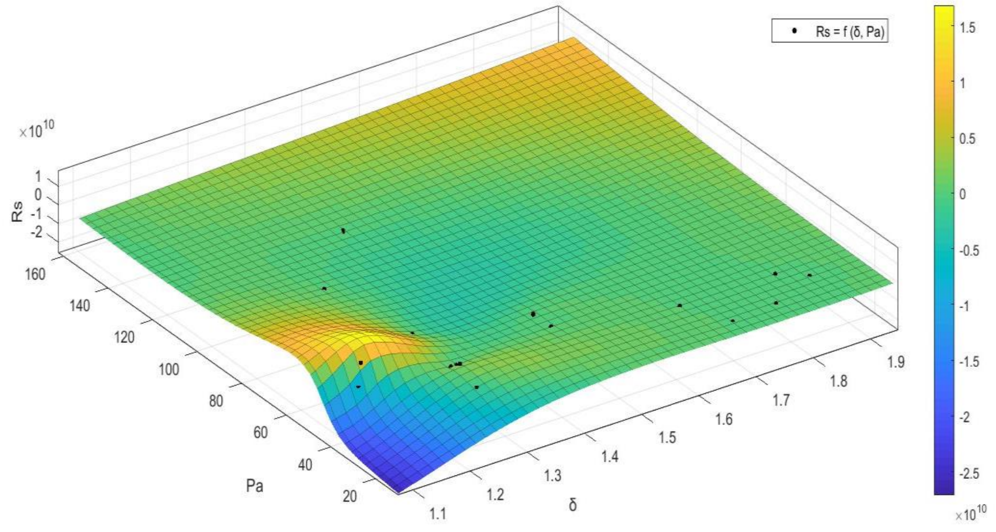

Fig. 2: 3D representation of the surface resistance (Rs) depending on air permeability (Pa) and thickness (δ)

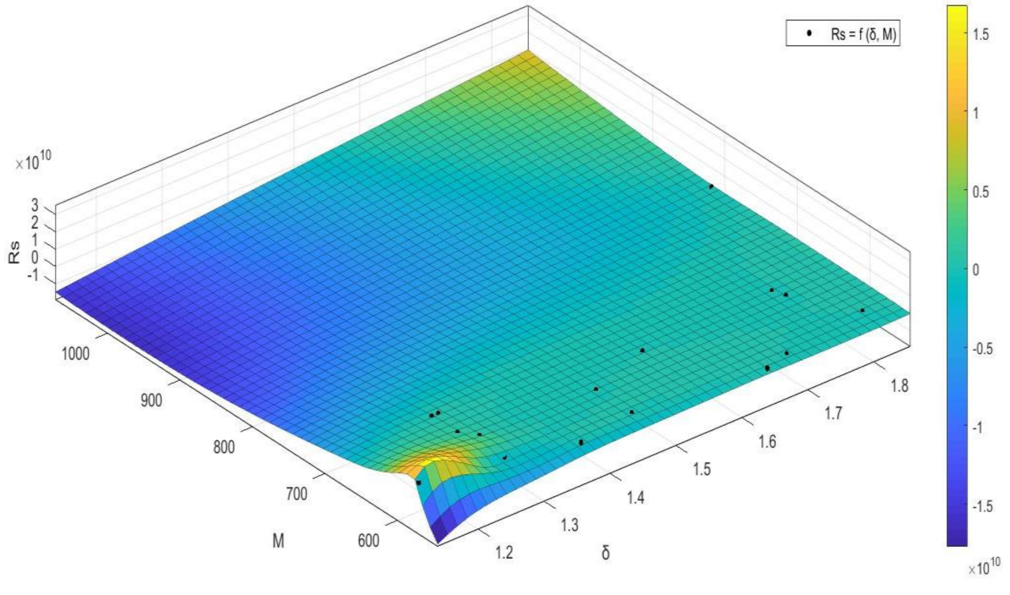

Fig. 3: 3D representation of the surface resistance (Rs) depending on mass (M) and thickness (δ)

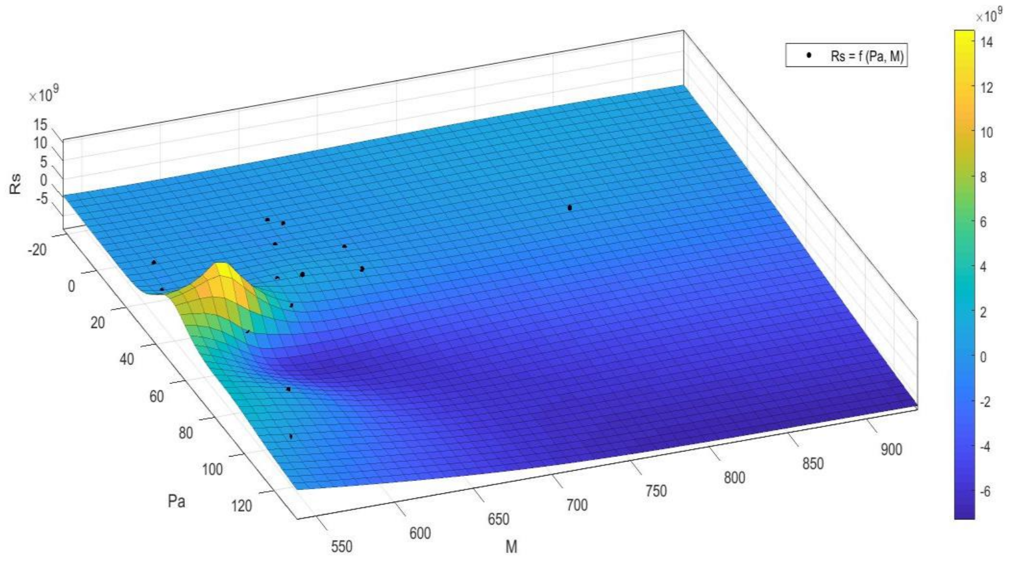

Fig. 4: 3D representation of the surface resistance (Rs) depending on mass (M) and air permeability (Pa)

5. CONCLUSIONS

It can be concluded that the conductivity is in inverse correlation with electrical surface resistance and air permeability and direct correlation with the mass and thickness of the conductive materials. However, the increase of the conductivity at the same time with the mass and thickness of the material is not appropriate sometimes because this means that the materials having an increased thickness will face the reduction of flexibility, being very difficult for wearing or wearable application. In addition, this increase in mass/thickness can reduce the adhesion when the materials are subject to mechanical demands when washing. From this point of view, if the conductive textile is not for single use and is necessary for repetitive washing cycles, it is recommended that the conductive layer's thickness be reduced to keep the material flexible.

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ANNALS OF THE UNIVERSITY OF ORADEA
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CIRCULAR ECONOMY AND RECYCLING IN THE TEXTILE INDUSTRY

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Abstract: *The paper analyses the transition from a linear economy paradigm to a circular economy model in the textile industry, which is one of the most polluting industries in the world. The linear model involves a large consumption of raw materials and generates waste, while the circular economy model focuses on the regeneration of raw materials and recycling. This includes the 5 R's of textile waste management: rethink, reduce, reuse, recycle, and reintroduce. The circular economy is characterized by close cycles, in which waste is minimized or converted into valuable inputs. Textile recycling process can be mechanical, thermal, chemical and biological. A series of recycling methods for different fiber-based materials: cotton, wool, synthetic, which are proposed in scientific papers is presented, contributing to the promotion of a zero-waste world.*

Key words: *sustainability, sorting, textile waste*

1. INTRODUCTION

In the current context of the growing importance of environmental protection in parallel with the sustainability of production activities and beyond, the textile industry is facing a change in strategies and process approaches in relation to the purpose and the profit obtained. A number of textile companies implement sustainable production systems, and others take into account principles such as sustainable sourcing of materials from suppliers who use ecological practices. Modern manufacturing processes enable harmful substances to be caught and repurposed as opposed to being dumped into the environment. At the same time, a new business model is used in the fashion industry, the circular economy (see fig. 1).

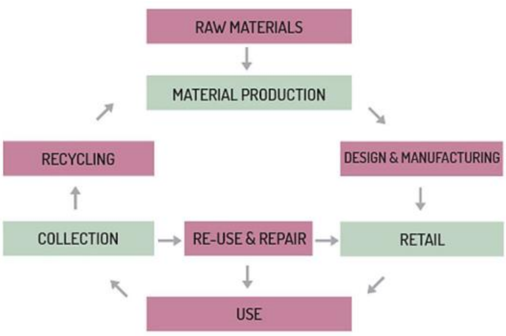

Fig.1: Circular economy in textile and apparel industry [1]

2. LINEAR AND CIRCULAR ECONOMY MODEL IN TEXTILE INDUSTRY

Clothing manufacturers also involve consumers in using sustainable consumption practices. By promoting ecological products, consumers learn about the benefits of circular fashion, which involves reusing and recycling of apparels. The 5 R's of textile waste management, which are rethink, reduce, reuse, recycle, and reintroduce, are crucial strategies for addressing the issue of textile waste. These tools enable us to conserve natural resources, reduce the amount of waste sent to landfills, and save energy [2].

Due to the fact that the textile sector ranks second in terms of pollution, contributing 10% of yearly worldwide greenhouse gas emissions and 20% of global industrial water pollution [3], it attempts to replace the traditional linear textile business model, which involves a large consumption of raw materials and the generation of waste [4]. To this practice is also added the Fast Fashion behaviour (the manufacturing and consumption of a lot of inexpensive, low-quality clothing with widespread use of micro plastics and other cheap raw materials [5]) which could be observed until the 2020s and which had the effect of doubling sales and decreasing the number of wearing of clothing products [4].

Limited natural resources, the polluting effects of waste, also utilizing non-renewable energy, represent environmental protection issues that are critical in approaching the linear economy. The solutions to these problems are given by the circular economy model, which focuses on the regeneration of raw materials and recycling. Clothing recycling increases the circularity of products and increases the life of textile materials. Textile fibers remain in the cycle longer and it is no longer necessary to be incinerated or stored [6] as waste as in the linear model. The circular economy is characterized by close cycles, in which waste is minimized or converted into valuable inputs, contributing to increasing productivity, optimizing the using of natural and human resources.

The management of the circular flow of materials must take the product's life cycle under consideration. Innovative strategies include item resale, rental, peer-to-peer sharing, collecting and exchange systems. As the product's life cycle is finished, its decommissioning is done by deconstructing and recovering the components without contaminating the ecosystems. If the garment can no longer be worn, textile resources are recovered by separating the fibers and regenerating them to new fabrics, as buildings materials [7].

3. TEXTILES RECYCLING

Waste is generated in the textile industry, both during the manufacture of textiles and the usage of the products, as post-industrial (pre-consumer) or post-consumer waste as shown in table 1. Pre-consumer waste refers to fibers, yarns, fabrics made of wool, acrylic, nylon, polyester, cotton and other materials, which originate from various operations of textile production, such as spinning, weaving, knitting, sewing, etc. Post-consumer waste originates from used textile products.

By recycling, the textile waste is eliminated from the stream, reprocessed and reintroduced it into the market to be used for creating new textile or non-textile goods. Pre-consumer waste is derived and used for automotive, aeronautics, housing, furniture, mattresses, coarse yarn and clothing, as post-consumer waste consists in textile that the user evaluates to no longer require and decides to throw away because they are worn, damaged or out of date [8].

Textile recycling can be mechanical, thermal, chemical and biological [9]. Mechanical recycling breaks down waste into fibrous forms which can be re-spun into yarns or processed into nonwoven, to use for decoration, construction, agriculture and gardening. Mechanical recycling has the advantage of being able to process fabrics made from any type of fiber and fiber mix.

Mechanical recycling is typically used for pre-consumer textile waste, which does not suffer wear and tear and is of better quality than post-consumer waste [10]. Recycling of unwearable, ripped, or stained clothing can be done by breaking down the fabric into fibers by shredding, cutting, carding etc. The fibers will then be used for other textile products such as padding, automotive outlines and coverings, building materials such as insulation and roofing felt, as well as blankets, carpeting, furniture upholstery, insulating materials and toys.

Table 1: Textile waste

Waste	Type of textile waste	Source of waste (section)
Post-industrial (Pre-consumer, production)	Blending, carding, dropping wastage, sliver, draw and ring frame waste	spinning
	Weaving, sizing, knotting, beam residual, auxiliary selvage wastage	weaving
	Samples, fabrics with stains, bareness, stripes, hole, thick, thin yarns	knitting
	Shade variation, crease	dyeing
	Cutting, sewing, finishing, printing, embroidery waste	garmenting
Post-consumer	Garments, home textiles, technical textiles, nonwoven	final consumer

Closed-loop mechanical recycling is a process that involves breaking down waste textiles into individual fibers without compromising their mechanical properties such as rigidity and strength. On the other hand, open-loop mechanical recycling entails cutting fibers prior to undergoing the melt-blowing process where they are disintegrated into individual fibers. The resulting fibers are then web formed and dried to produce the final product. This method is commonly used in manufacturing individual pads for mattresses.

Thermal recycling refers to the conversion of thermoplastic waste, typically polyester flakes, into fibers through the melt extrusion fiber production process. Recycled polyester fibers from plastic bottles are obtained through thermal recycling [10].

Chemical recycling has two variants: synthetic polymers fibers are depolymerized into monomers and then repolymerized into polymers, as well as regenerated cellulosic fibers are created by wet spinning natural or recycled cellulosic fabrics that have been dissolved in a solvent.

Chemical recycling involves the depolymerization of polymers, such as polyester, or the dissolution of materials like cotton and viscose. Through this process, fibers of similar quality to virgin materials can be produced [11]. Through chemical treatment, textile waste with protein-based fibers can be used to make adhesives for wooden panels, and those with cellulosic fibers used for bioethanol process [12]. The products obtained from glycolysis of PET waste will serve as building blocks for the synthesis of degradable co-polyesters. By performing amylolysis in the presence of amino acids, nylon 6 and nylon 6.6 are transformed in other substances. Hydrolysis is a versatile process that can be employed to treat mixed fabrics such as cotton, wool, and polyester. While there are various types of hydrolysis, enzymatic, alkali, and acid hydrolysis have gained more popularity in recent times.

To enable thermal and chemical recycling of textiles composed of fiber blends, it is essential to ensure a high degree of material purity, which necessitates the sorting and separation of such materials.

The process of biodegradation involves the natural recycling of waste and the breakdown of organic materials by microorganisms like fungi, bacteria, worms and insects. Biochemical transformation by fermentation is a way of using recyclable cotton textile waste into new products. Utilizing solid waste from the textile industry for biogas production via anaerobic digestion presents an alternative approach [9]. Enzymes function as biocatalysts, accelerating the rate of chemical reactions. They exhibit remarkable specificity, selectively acting on particular substrates to produce desired products. One example of this is cellulose, which can be sourced from fungi and bacteria, and is utilized in cellulose hydrolysis.

Medical textiles can currently be recycled completely through various methods such as chemical treatment, incineration, and autoclaving. However, the latest and most inventive solution for recycling medical textiles involves molecular tagging of fibers [13].

4. THE SORTING PROCESS

The sorting of post-consumer waste begins with the selection of heavy items from the lightest, followed by the separation by product categories, fabric and gender, raw material (wool, cotton, linen), conditions (tear, missing buttons and wear), quality and degree of use [14]. Following collection, textiles are sorted by color and material to enable efficient processing. Fabrics or garments with similar characteristics are grouped together and processed in batches. Components that are not made of textiles, like zippers and buttons, are extracted, and the remaining material is cut into uniform sizes to facilitate processing. To ensure smooth machinery operation, waste is blended with oils. Depending on the type of material, suitable methods such as physical or chemical techniques are used to further break down the material. The resulting fibers are then carded and/or spun into yarns, which are used to create value-added products.

The mechanical recycling of thermoplastics, such as polyolefin, polyester, polyamides, and other plastic products and textile materials, involves melting, shredding, or granulation of the waste. To achieve efficient mechanical recycling, it is essential to maintain the purity of the final product, and therefore, sorting of waste materials before recycling is necessary to prevent contamination that may considerably decrease the value of the recycled fibers. Sorting of plastic waste is typically based on color and chemical structure and can be carried out manually or by machine. Manual sorting consumes time and is not very rigorous, which is why automatic sorting is a better alternative. Various techniques, as X-ray fluorescence, near-infrared spectroscopy, flotation and electrostatics are introduced to sort plastics automatically [15]. In recent times, hydrocyclones, which were originally employed in mineral separation and other industries, have found application in plastic separation processes.

The Pyramid Model in fig. 2 specifies the categories that will determine which processes will be supported next: recycling or reuse of the textile material. These categories are: textiles for used clothing markets, conversion textiles, wiping and polishing clothes, textiles sent to landfills and incinerators and diamonds [16].

Diamonds (1-2% of recycled textiles) are older clothing items from well-known brands: couture, Levi's, Ralph Lauren, Dona Karan, Harley Davidson, and expensive fibers, as cashmere and camel hair. There is significant demand for second-hand clothing, which can be sold online, in vintage or retail boutiques. Only around 7% of recycled textile products are either incinerated or sent to landfills. Textiles that end up in landfills lose their value and cannot be repurposed, making it important to avoid incineration and minimize losses. This practice is applied especially in Europe, aiming to increase the efficiency of incineration and reduce the harmful by-products of incineration.

About 17% of used textiles are included into the category of wiping and polishing cloths, being considered unwearable. This group encompasses blends of hydrophilic and oleophilic fibers that are frequently beneficial in industrial settings. It also includes T-shirts made of cotton fibers renowned for their high absorbency.

Approximately 29% of textile waste is repurposed into new products if it is considered unsuitable for further use. The terms "shoddy" (for knits) and "mungo" (for woven garments) refer to the process of converting fabric into fibers through mechanical means. The shoddy method involves creating new yarn products from old materials and is often utilized in producing knit blankets. The term "mungo" pertains to the process of utilizing textile waste to produce cloths in cold climate countries. Shoddy and mungo fibers are used for cashmere sweaters, the filling material used for furniture, automobiles, and punching bags.

Fig.2: The Pyramid Model for textile recycling categories [16]

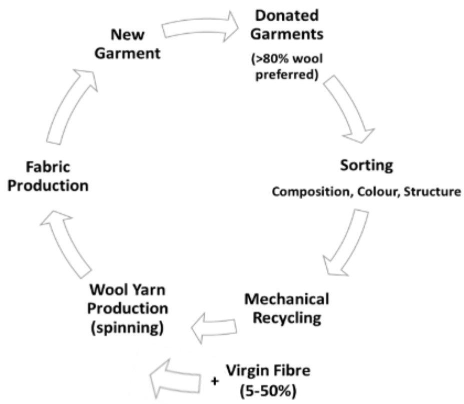

Fig. 3: Recycling of wool closed - loop [29]

48% of textiles are classified in the category of used clothing markets. Western countries engage in the exportation of used textiles to developing countries or use them for humanitarian aid purposes during times of crises or emergencies.

5. CATEGORIES OF TEXTILE RECYCLING

5.1. Cotton fibers

Polyester and cotton are the most common fibers used worldwide. Cotton is a natural fiber which can be recycled mechanically, chemically, or biologically. However, cotton recycling can be complicated by the presence of contaminants such as dyes and finishes, and mechanical recycling can weaken the fibers.

During the production of cotton garments, there is an estimated global generation of approximately 11.6 million metric tons of waste cotton each year. The cotton recycling process refers to the mechanical processing and re-spinning of residual waste. Due to the fiber-breaking nature of the mechanical process, the quality and strength of the recovered fiber are typically diminished. Consequently, the recovered fiber must be blended with either virgin cotton fibers or other types of fibers to enhance its strength. Cotton as a raw material is used in non-woven surfaces for insulation, automotive felts, and oil absorbent films. Recycling cotton fibers offers ecological benefits, including 20% lower water and energy consumption, a reduction in chemical use, and fewer emissions generated. The elimination of agricultural operations associated with conventional cotton production also leads to a decrease in the consumption of natural resources [17].

Several studies have been conducted on recycling of cotton waste. In [18], the authors explored various techniques for recycling pre-consumer and post-consumer cotton waste, including chemical and mechanical processes. They also compared the applications of waste cotton to their virgin counterparts from technical, environmental, and economic viewpoints. The study also included non-conventional applications of waste cotton, as biofuels and composites, which could open up alternative markets for waste cotton that do not conflict with the use of virgin cotton.

Paper [19] investigates the feasibility of recycling cotton waste into usable yarns for textile production. The study involved the collection of cotton fabric scraps from a local garment factory and the processing of the scraps into yarns using a semi-industrial machine. The authors examined the effect of different processing parameters, such as carding, combing, and drafting, on the quality of the recycled yarns. They analyzed the physical properties of the yarns, such as thickness, strength, and elongation, and compared them to those of virgin cotton yarns. The results showed that the recycled yarns had similar physical properties to those of virgin cotton yarns, indicating that cotton fabric scraps could be successfully recycled into usable yarns.

The authors of [20] used a mechanical recycling process in optimizing the recycling process of waste cotton yarn and spinning of reclaimed fibers to produce value-added products. They tested various spinning parameters to optimize the production of yarn. The optimal spinning conditions for the reclaimed fibers were a draft ratio of 1:9 and a spindle speed of 12000 rpm.

The Cotton Waste Recycling for Regenerated Cellulose Fibers is the subjects of [21] and [22]. In [21], the physical properties of the resulting fibers, such as their tensile strength, elongation at break, and thermal stability, are evaluated, being found as a potential alternative to traditional textile fibers. Paper [22] proposed a process for recycling post-consumer cotton waste into regenerated cellulose fibers, which involved several steps, including pre-treatment, dissolution, regeneration, and spinning. The authors investigated the effect of a chelating agent use during pre-treatment, which improved the purity and mechanical properties of the regenerated cellulose fibers.

The chemical recycling of cotton materials and other cellulosic textiles to produce high-quality regenerated textile fibers is a new process that aims to address concerns related to the growth of the population, scarcity of resources, and adverse environmental effects caused by the textile industry. The authors of [23] present an overview of the various chemical recycling techniques, such as hydrolysis, pyrolysis, and solvolysis, and their respective advantages and disadvantages.

In [24] researchers have developed a new method for depolymerizing cotton waste textiles to form a glucose solution using sulfuric acid as a catalyst, with a high yield of over 70%. The method is applicable to various types of cellulosic fibers; the high concentration of glucose produced (>100 g/L) reduces the cost of purification, making the process more economically viable. This method has the potential to not only reduce textile waste but also to create a closed-loop system within the textile value chain, retaining the value of waste textiles and reducing the industry's reliance on virgin materials. The methods proposed in [25] and [26] refer to solubilizing cotton post-consumer textile waste in the cellulose-dissolving ionic liquid ([DBNH]OAc) to be transformed into continuous filaments. However, due to the heterogeneous nature of the raw material, it was necessary to pre-treat the waste cotton to modify the degree of cellulose polymerization by acid hydrolysis, enzyme hydrolysis, or mixing with birch pre-hydrolyzed kraft pulp to improve spinnability. In comparison to native cotton fibers and other commercially available fibers such as viscose and lyocell, all of the regenerated fibers during Ioncell® process [26] display considerably higher tenacities of approximately 60 cN/dtex with a 10% elongation. Fibers produced from dyed cotton experienced a decrease in color intensity and a minor reduction in crystallinity after spinning, but no notable changes in the chemical structure were observed.

Paper [27] presented a reuse of waste cotton fibers method by milling them into fine powders with particle sizes of approximately 30 µm and dyeing them for use as pigments. The study used several methods, including dynamic mechanical analysis, scanning electron microscopy, Fourier-transform infrared spectroscopy and X-ray photoelectron spectroscopy to explore the properties of the powders and indicated that the material underwent primarily viscous deformation. Using similar assessment methods, the proposed approach from article [28] refers to the woven cotton fibers degradation at 50°C with low concentrations of urea, citric acid, sodium hydroxide ammonium hydroxide and sodium nitrate which successfully separates the component fibers besides depolymerization of the cellulose structure. The study proves that it is feasible to recycle waste fabric effectively through non-chemical intensive procedures, as it is possible to recover the staple fibers and reuse them in the production of new textiles.

5.2. Wool fibers

Wool is a natural fiber that can be recycled mechanically or chemically. Wool fibers have unique properties such as elasticity and moisture management, but they can be challenging to recycle because they can become damaged or matted during processing. Additionally, wool recycling can be complicated by the presence of additives and finishes.

Recycling wool fibers in a closed loop system is possible, and traditional methods can transform recycled wool yarns into high-value apparel products. The process of wool recycling is similar to mechanical cotton recycling (see fig. 3) [29], [30].

Paper [31] aimed to determine the environmental and market impacts of the recycled wool blend clothing production. During a cradle-to-grave life cycle assessment, the study emphasis that by using best practices for garment maintenance; a recycled wool blend sweater can decrease environmental impacts by 66-90% in comparison to a new pure wool sweater. Furthermore, if the closed-loop recycling rate were increased to 50%, it could potentially reduce impacts on the wool sweater market by 7-24%, depending on the specific impact category.

The products of recycled wool may be of lower quality than the original materials, but they can still be used in various applications such as insulation, carpeting, or padding. Other applications, including biomaterials, resins, and adhesives, are created by extracting the keratin protein from pre- and post-consumer waste. Researchers have also explored using recovered proteins from recycled or waste wool like functional treatments in wool fabric manufacturing. For instance, Smith and Shen [32] separated polypeptides from waste wool of low quality to change the surface properties of wool fibers and enhance shrink resistance. Similarly, Du et al. [33] designed a finishing method for wool fabric that prevents felting and pilling through the use of keratin polypeptides separated from recycled waste wool, which also improved the softness, dyeability, and hydrophobicity of the treated fabrics.

5.3. Synthetic fibres

Approximately 72 per cent of all materials used by the fashion industry are made from plastic [34]. 500000 tons of microfibres are released into the ocean each year from washing clothes - the equivalent of throwing 50 billion plastic bottles [4]. These fibres can take up to 200 years to decompose.

Synthetic fibers such as polyester, nylon, and acrylic are derived from petrochemicals and are not biodegradable in the standard conditions. Synthetic fibers can be recycled chemically or mechanically. Chemical recycling of synthetic fibers can be energy-intensive, and the process often requires high temperatures or strong solvents. Mechanical recycling can be more challenging for synthetic fibers because they are often blended with other materials, making it difficult to separate and recycle them [35].

Recent articles cover strategies and novelties in enhancing the biodegradability of synthetic textile fibers. In paper [36], the use of polylactic acid is proposed as a biobased and biodegradable alternative apparel textile fiber, while biological methods are suggested for addressing PET waste, such as industrial enzymatic hydrolysis for creating recyclable monomers. Although pure PET fibers do not biodegrade under standardized conditions, recent advancements in process intensification and engineered enzymes have shown greater enzymatic recycling efficiency for PET polymer in comparison to cellulosic materials. Also, the development of synthetic/natural fiber blends and novel waste management techniques like compost, anaerobic treatment, and biocatalyzed industrial reworking are opening up potential for new environmentally friendly and recyclable textile fibers.

The mechanical properties of recycled PET yarns are often inferior to those of virgin PET (v-PET) yarns due to impurities originating from non-PET sources like labels and caps of bottles. As a result of growing environmental concerns, the recycling of post-consumer plastic containers into textile fibers has made economically viable. In [37], the authors investigated the impacts of mechanical and chemical recycling processes on yarn properties such as photo-degradation, tensile strength, thermal behavior and hydrolysis. The virgin and chemically recycled yarns have related physical, mechanical properties and long-term degradation behavior. These results offer valuable insights into the processability and serviceability of recycled PET (r-PET) yarns, especially for high-end use applications.

Paper [38] consists in a study of the liquid moisture transfer properties of polyester and recycled polyester knitted fabrics, concluded in the r-PET fabric had better results than the PES fabric in terms of absorption rate, wettability, drying rate, and capillarity.

The authors of [39] propose a twisting technique to enhance the mechanical characteristics of the yarns made from recycled plastic bottles and make them more suitable for use in high-performance reinforced composites.

Fabrics that are often recycled contain cotton and polyester. Clothing products such as shirts, sportsuits, bags, coats etc. use recycled polyester. The study from [40] emphasis that the recycled PET fiber is a suitable component for cotton blended yarn production. The recycled PET yarn exhibits reasonable degrees of unevenness, hairiness, and elongation when compared to virgin PET yarn. However, the recycled PET yarn's decreased strength could be viewed as a drawback.

The paper by dos Santos Pegoretti et al. [41] presents a comparative life cycle assessment case study about the acoustic components used in the automotive industry, with a focus on the environmental effects of using recycled versus virgin materials. The authors also evaluated the economic feasibility of using r-PET fibers, concluding that the cost of using r-PET fibers was comparable to the cost of using virgin materials.

5. CONCLUSIONS

Recycling presents unique challenges and benefits for each material. Successful recycling depends on various factors, such as the presence of contaminants, availability of appropriate recycling facilities, and markets for recycled products. Despite the difficulties, natural fibers like cotton and wool are biodegradable and have a lower environmental impact than synthetic fibers, which are made from non-renewable resources and can persist for centuries. To close the fashion loop, brands must assume full responsibility for their products until their end-of-life, implementing sustainable solutions like reselling, clothes swaps, take-back programs, repairing schemes, and upcycling. These strategies can divert textiles from landfills, support decarbonization, and promote a zero-waste world.

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ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

EFFECT OF ELASTANE ON DIMENSIONAL AND THERMAL PROPERTIES OF SPORTSWEAR FABRICS

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Abstract: *In recent years, the use of woven and knitted fabrics with elastane has increased remarkably. This is due to the particular fact that these articles are characterized by excellent wear comfort and fit. In addition to extensibility, thermo-physiological comfort properties such as air permeability and thermal properties can be influenced by elastane yarn. This paper aimed to investigate the relation between elastane yarn linear density and fabric dimensional and thermal properties. Two series of 3 knitted fabrics were produced using the 8-feed Single-Jersey Circular Knitting Machine MERZ – MBS. The ground yarns were: 30% Outlast®Viscose / 70% Cotton, 14.75 tex, and a Dacron® 702 WSD 1.7/38, 14.30 tex (Coolmax®). The plating yarns were 22 dtex, 44 dtex, and 77 dtex Creora®, plated at every feeder by using the electronic feeder. The results indicated that the linear density of elastane has a significant effect on the dimensional and thermal properties of Coolmax®/Creora® and Outlast®/Creora® plated plain knitted fabric. The elastane yarn linear density mainly influences the number of courses per cm and consequently the number of stitches per cm^2, and respectively the weight of knitted fabrics. The linear density of elastane yarn influences mostly the air permeability, thermal conductivity, and thermal absorptivity of Single-Jersey fabrics. The higher the linear density of the elastane yarn, the lower the air permeability and the higher the thermal conductivity and thermal absorptivity of the fabrics. These findings are an important tool in the design of a product tailored to thermal management requirements.*

Keywords: *knitted structure, thermal resistance, thermal conductivity, thermal absorptivity, air permeability.*

1. INTRODUCTION

Nowadays, more and more articles for sportswear, underwear or outer clothing include elastane yarn. Stretch garments play an important role in optimizing an athlete's performance by providing freedom of movement, maximizing comfort, minimizing the risk of injury or muscle fatigue, and reducing friction. According to the literature, to improve fabric elasticity and shape retention, 2% of elastane is enough but for high-performance garments, such as swimwear and active sportswear, the elastane content can increase up to 30% [1], [2].

Elastane fibers are synthetic fibers made of polyether-polyurea copolymer, known for their exceptional elasticity. The stretch elasticity of elastane can be as high as 500% while the elastic recovery reaches 95%. The first process of the industrial-scale production of elastane was developed in 1958 by Joseph Shivers, a chemist at DuPont's Benger Laboratory, in Waynesboro, Virginia, US.

Initially, DuPont chose the name „Lycra" to distinguish its brand of elastane fiber [3]. Nowadays brand names for elastane fiber include Lycra® and Elaspan® (Lycra Company, previously a division of DuPont Textiles and Interiors), Acepora® (Taekwang Group), Creora® (Hyosung Corporation), INVIYA® (Indorama Corporation), ESPA® (Toyobo Co., Ltd.), ROICA®, Dorlastan® (Asahi Kasei Group), Linel® (Fillattice Group), etc. For articles with high elasticity (tights, underwear, swimwear, beachwear, sportswear, corsets, and medical support stockings, etc.) elastane fibers are always mixed with one or more other fibers, and the most used technological method for obtaining these products is that of knitting. If bare elastane yarn is processed to form a loop it must always be knitted together with ground yarn [3].

Plating (the simultaneous formation of the loop from two threads) is a common way of processing stretch-knitted fabrics. Some research available in the literature described the relation between the rate of elastane (respectively elastane yarn tension) and the dimensional and elastic properties of the fabric [4], [5], [6]. Other studies focused on the behavior of fabric with elastane yarn during stretching. The results of these studies demonstrated that elastane changes the dimensional characteristics of the fabric and the stretch properties [7]. Anyway, the relation between elastane proportion and fabric characteristics has not been enough studied, and generally, in practice, the experience is used during machine adjustments to reach the required fabric characteristics. Moreover, the changes in the dimensional characteristics of fabric can affect its thermal properties and little work has been done on the study of the effect of elastane on the thermo-physiological comfort properties.

In this paper, the relation between elastane yarn linear density and fabric dimensional and thermal properties was investigated.

2. MATERIALS AND METHODS

Two series of 3 single jersey knitted fabrics were produced using the 8-feed Single-Jersey Circular Knitting Machine MERZ – MBS. The ground yarns were: 30% Outlast®Viscose / 70% Cotton, 14.75 tex, and a Dacron® 702 WSD 1.7/38, 14.30 tex (Coolmax®). The plating yarns were 22 dtex, 44 dtex, and 77 dtex Creora®, plated at every feeder by using an electronic feeder BTSR KTF 100 HP. The plating yarn input tension was 4 cN and for the main yarn 2 cN.

Dry relaxation was made by laying the samples on a flat surface under atmospheric conditions (20 ± 2°C and 65 ± 5% relative humidity) for 48 hours.

The single jersey knitted fabric characteristics measured were wales density, courses density, loop length, fabric weight per unit area, and fabric thickness. The wales and courses density of knitted fabrics were measured according to the ASTM D-3887-2008 standard. Maillemètre was used to determine the loop length following BS EN 14970-2006 – „Textiles. Knitted fabrics. Determination of stitch length and yarn linear density in weft knitted fabrics". The length of ten unrow courses, each of them containing 100 wales, was measured on a Maillemètre tester, and an average was calculated. This average value was divided by 100 to find the length of one loop. The tightness factor was also calculated as follows [8]:

$$Tightness\ factor = \frac{\sqrt{T_{tex}}}{L} \quad \textbf{(1)}$$

where: T_{tex} is the linear density of the yarn, and L - the loop length, in mm.

The fabric mass per unit area was measured according to ASTMD 3776/D 3776M - 09a using an electronic balance KERN-770 with an accuracy of 0.1 mg. The thickness of the knitted fabrics was determined with SDL – Digital Thickness Gauge M034A, according to NP EN ISO 5084-1996.

The thermal properties of the fabrics were measured by the ALAMBETA instrument [9] according to ISO EN 31092-1994. The measurements were repeated 10 times on randomly chosen parts of the fabrics, and average values were calculated. The measuring head temperature of the ALAMBETA was 32 °C, and the contact pressure was 200 Pa.

Thermal comfort is characterized by three important properties: thermal conductivity, thermal resistance, and thermal absorptivity.

Thermal conductivity, λ (W/mK), is considered to be dominant in determining heat transfer through fabrics and garments. The measurement result of thermal conductivity is based on Eq. (2):

$$\lambda = \frac{Q}{F\tau\frac{\Delta T}{\sigma}} \quad (W/mK) \tag{2}$$

where: Q is the amount of conducted heat, F - the area through which the heat is conducted, τ - the time of heat conducting, ΔT - the drop in temperature, and σ - the fabric thickness.

Thermal resistance, R (m^{2}K/W), mainly depends on the thickness and porosity of the fabric. Thermal resistance is connected with fabric thickness by the relationship:

$$R = \frac{\sigma}{\lambda} \quad (m^2K/W) \tag{3}$$

where: σ is the fabric thickness, and λ - the thermal conductivity.

Thermal absorptivity, b (Ws$^{1/2}$/Km^2), is the heat flow q (W/m^2) which passes between the human skin and the contacting textile fabric. The higher this value, the cooler the feeling represented.

$$b = \sqrt{\lambda\, \rho\, c} \quad (Ws^{1/2}/Km^2) \tag{4}$$

where: λ is the thermal conductivity, ρ - the fabric density, and c - the specific heat of the fabric.

The air permeability of the samples was measured according to ISO 9237-1999 with a Textest FX-3300 air permeability tester. The air pressure differential between the two surfaces of material was 100 Pa, the measurements were carried out 10 times and the average and standard deviation of the test values were calculated.

3. RESULTS AND DISCUSSION

One-way ANOVA analysis was carried out to determine the influence of elastane linear density on the dimensional and thermal properties of knitted fabrics, using the professional statistical software PASW Statistics 17.

3.1. Dimensional properties

The dimensional parameters of the fabrics are given in Table 1.

Table 1. Dimensional properties of knitted fabrics

Elastane linear density	Wales/cm		Courses/cm		Stitch/cm²		Tightness factor, $T_{tex}^{1/2}$/mm		Weight, g/m²	
	Coolmax® + Elastane	*Outlast® + Elastane*	Coolmax® + Elastane	*Outlast® + Elastane*	Coolmax® + Elastane	*Outlast® + Elastane*	Coolmax® +Elastane	*Outlast® + Elastane*	Coolmax® +Elastane	*Outlast® +Elastane*
77 dtex	17,5	*17,5*	40	*40*	700	*700*	1,67	*1,66*	307,59	*313,2*
44 dtex	17	*17*	34	*34*	578	*578*	1,49	*1,48*	253,78	*253,2*
22 dtex	16,5	*16,5*	27	*28*	445,5	*462*	1,37	*1,37*	182,24	*206,46*

The elastane yarn linear density mainly influences the number of courses per cm and consequently the number of stitches per cm^2. Higher linear density gives a higher value of courses per cm and respectively stitches per cm^2 because the tension applied by elastane yarn is higher and makes stitches closer to each other.

The loop length of ground yarn decreases when the elastane yarn linear density increases (Fig. 1). The influence of elastane yarn linear density on loop length is significant at a 95% confidence interval. Ground yarn consumption is constant but stitch geometric configuration is modulated by the tension applied by the elastane plating yarn. The tension applied by thicker elastane yarn is higher and consequently, the loop length is lower. This reduction in loop length with increasing the linear density of the elastane yarn also accounts for the variation in the density of the courses and stitches.

The tightness factor is directly proportional to the linear density of the elastane yarn.

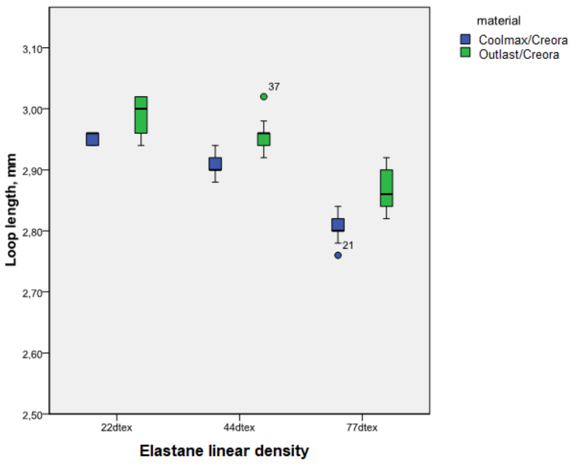

Fig. 1: Loop length

The thickness of the fabrics increases slightly with the linear density of the elastane yarn due to the higher tension exerted by the elastane yarns (Fig. 2). The thickness of Coolmax® fabrics is higher than that of Outlast® ones, although the fineness of the Outlast® yarns is slightly lower (Table 1). This is due to the characteristics of the yarns (eg stiffness) related to the type of raw material and the internal structure of the yarn (eg fiber stiffness, twist).

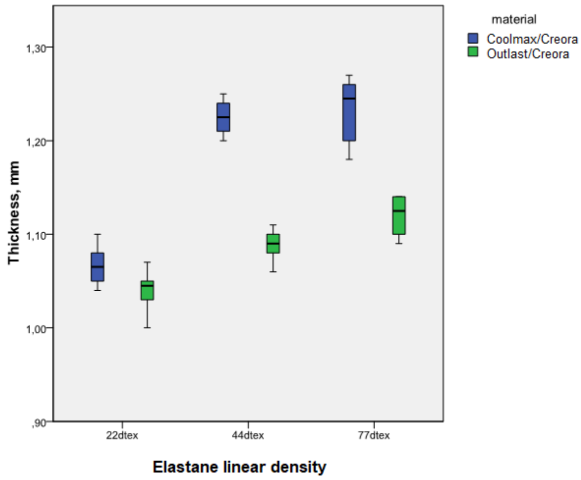

Fig. 2: Thickness

The weight of the samples also increases as the linear density of elastane yarn increases because the loop length decreases and, the greater the amount of elastane percentage the tighter the fabric (Table 1). Thus, the fabric becomes thicker and heavier as the proportion (yarn linear density) of elastane increases.

3.2. The thermal properties

Thermal conductivity

The Outlast® fabrics have higher thermal conductivity than Coolmax® fabrics (Fig. 3), and the differences are significant at a 95% confidence interval.

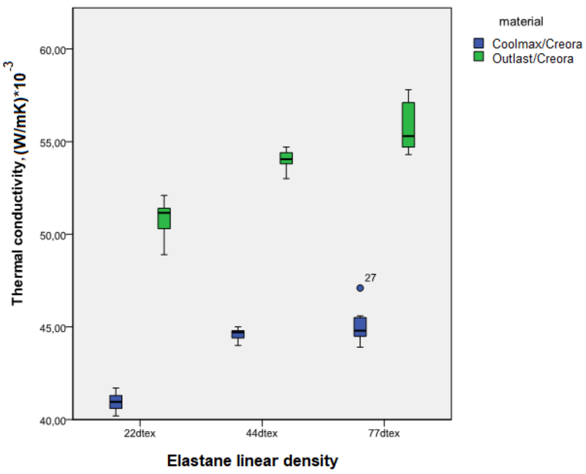

Fig. 3: Thermal conductivity

One-way ANOVA analysis revealed that there is a significant influence of the elastane linear density on the thermal conductivity of Single Jersey fabrics**.** The lower the linear density of elastane yarn (or the lower the tightness factor**)** the lower the thermal conductivity.

In the case of the Alambeta device, heat transfer through fabric mainly depends on thermal conductions, whereas heat loss by convection and radiations is negligible. For textile materials, still air in the fabric structure is the most important factor for thermal conductivity value, as still air has the lowest thermal conductivity value compared to all fibers (λ_{air} = 0.025 $W/(m \cdot K)$) [10]. Therefore, for fabrics with a lower tightness factor (lower linear density of elastane yarn), the enclosed air carries a reduced amount of energy by conduction, and the thermal conductivity also decreases.

Thermal resistance

Coolmax® fabrics have a higher thermal resistance (Fig. 4), so better thermal insulation properties. The elastane linear density does not have a significant influence on the thermal resistance of these knitted fabrics. Even if small differences are reported among the thermal resistance values, the differences are not statistically significant at a 95% confidence interval, and the influence of elastane yarn linear density on the thermal resistance of this type of fabric can be ignored.

According to Eq. (3), there should have been an inverse relationship between thermal resistance and thermal conductivity. However, the results revealed that as thermal conductivity increases, thermal resistance also increases slightly. This contradiction might be explained by the fabric thickness. A significant increase is registered in the fabric thickness, confirmed by ANOVA results. Thus, the increment in thermal resistance and thermal conductivity is normal.

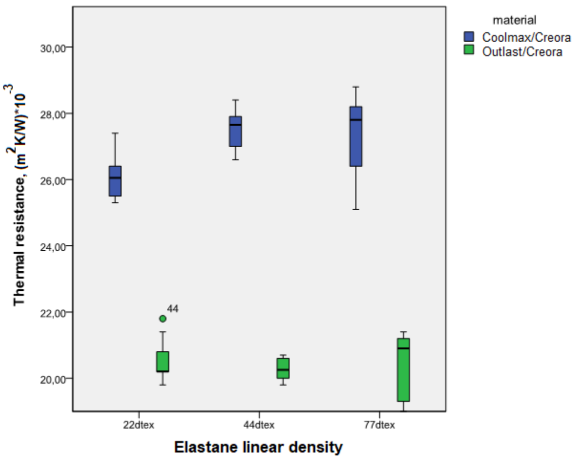

Fig. 4: Thermal resistance

Thermal absorptivity

Thermal absorptivity is the objective measurement of the warm-cool feeling of fabrics. When a human touch a garment that has a different temperature than the skin, heat exchange occurs between the hand and the fabric. If the thermal absorptivity of clothing is high, it gives a cooler feeling at first contact. The surface character of the fabric greatly influences this sensation. A rough fabric surface reduces the area of contact appreciably giving a warm feeling, and a smoother surface increases the area of contact and the heat flow, thereby creating a cooler feeling [7].

The raw material has a significant influence on thermal absorptivity. The Coolmax® fabrics having lower thermal absorptivity provide a warmer sensation at contact with the skin.

The ANOVA analysis showed that there is a significant influence of the elastane linear density on the thermal absorptivity of Single-Jersey fabrics**.** The higher the linear density of elastane yarn the higher the thermal absorptivity of the fabrics (Fig. 9). This is due to the fact that with thicker elastane yarn the surface of the fabric becomes smoother.

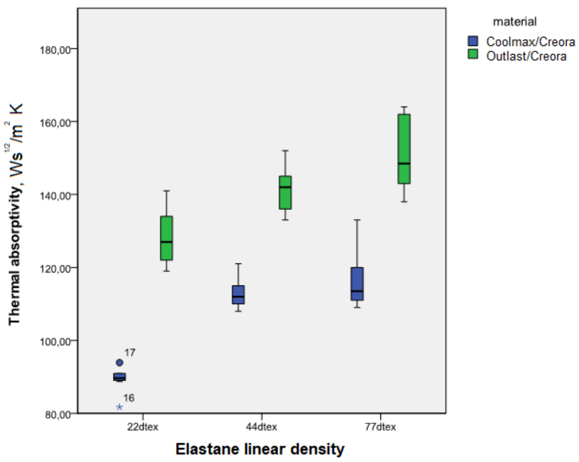

Fig. 9: Thermal absorptivity

Air permeability

Air permeability is described as the rate of air flow passing perpendicularly through a known area under a prescribed air pressure differential between the two surfaces of a material. Air permeability has a direct relationship with pores size. An increase in pores size led to an increase in air permeability. The fabric with the lowest stitch density has the best air permeability.

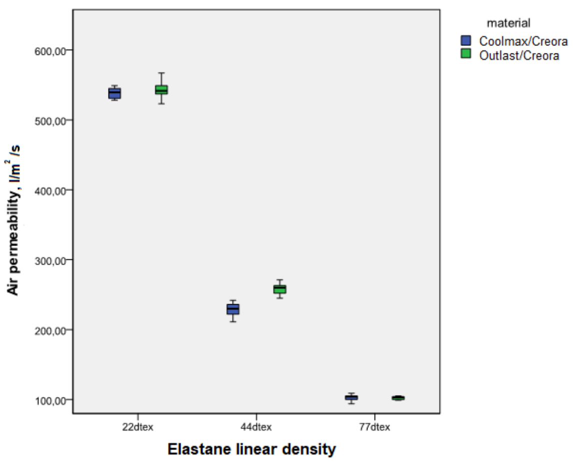

Fig. 10: Air permeability

One-way ANOVA analysis showed that there is a significant influence of the linear density of elastane on the air permeability of knitted fabrics. Air permeability decreases with the increasing linear density of elastane yarn (Fig. 10). This can be explained by the shrinkage of the fabric after knitting due to the relaxation of the elastane yarn. Greater yarn shrinkage at a higher percentage of elastane (higher linear density) provides a more compact and thicker structure, which results in less free space available for air movement.

4. CONCLUSIONS

The results obtained in the present work indicated that the linear density of elastane yarn has a significant effect on the dimensional and thermal comfort properties of Coolmax®/Creora® and Outlast®/ Creora® Single-Jersey plated knitted fabric.

The elastane yarn linear density mainly influences the course density and consequently the number of stitches per cm^2 and respectively the weight of knitted fabrics. The weight and thickness of the elastane-containing fabrics are higher as the linear density of elastane yarn increases and fabrics tend to be tighter.

The linear density of elastane yarn significantly influences the air permeability of the fabrics. The higher the linear density of the elastane yarn the lower the air permeability.

The linear density of elastane yarn has a significant influence on the thermal conductivity and thermal absorptivity of Single-Jersey fabrics**.** The higher the linear density of elastane yarn the higher the thermal conductivity and absorptivity of the fabrics. On the contrary, the significance values of the F test in the ANOVA for thermal resistance are above 0.05 for all samples, and this means that the elastane linear density does not have a significant influence on thermal resistance.

These results represent an important tool in the design of structures with specific thermal management requirements, to be used in functional sports clothing.

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ANNALS OF THE UNIVERSITY OF ORADEA
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ANALYSIS OF BREAKING CHARACTERISTICS OF COTTON FABRICS OF THE MOST FREQUENT WEAVES

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Abstract: *The behavior of three raw cotton fabrics of different basic weaves and approximate yarn settings and yarn counts, when subjected to tensile deformation, is described in this article. The values of the breaking force in the fabric in the linen weave have the highest mean numerical value, while the cotton fabric in the atlas weave has the lowest values. The fabric in the twill weave has the highest values for elongation at break, while the lowest values are present in the fabric in the atlas weave. The fabric in linen weave is the most resistant to external deformations, while the fabric in twill and atlas weaves are the weakest. The standard deviation and coefficient of variation for fabrics in all weaves have values that move within a range that confirms the validity of the results. In some cases, larger variations of these statistical data mean that these results can be taken with a certain amount of caution. It seems that there are a lot of latent stresses in the fabric, which are relaxed during the action of the tearing force, causing greater variations in the measurement results. Deformation curves after nonlinear fitting of the breaking force-elongation at break dependence are described by polynomial equations of the fourth and fifth degree, with the fact that about 99% of the variability of the dependent variable can be explained by means of the analyzed independent variables. Polynomial models are practically usable because they can predict with high reliability the deformation behavior of fabrics with similar weaves in the direction of the warp. There are statistically significant correlations between numerous values for breaking force from the experiment and the polynomial model.*

Key words: *cotton fabric, weave, breaking properties, correlation, polynomial regression.*

1. INTRODUCTION

Fabrics belong to the group of inhomogeneous materials with a very complex structure that originate from their building elements (fibers, yarns). The properties of woven materials are conditioned by the properties of all elements of lower structural rank that participate in their construction. Primarily, the properties of fabrics depend on the properties of the yarn, as its basic structural element [1,2].

Accurate prediction of fabric properties is a very complex issue that can be difficult to solve without simplification. The complexity of the problem arises from the fact that the properties of the fabric depend on the construction and technological parameters. Construction parameters include fineness and properties of warp and weft yarns, warp and weft density, and weave. Technological parameters are the type of loom and weaving conditions, i.e. warp and weft tension, weft feeding speed, beating-up motion force, etc. [3-5].

In this work, the behavior of three cotton fabrics with different basic weaves and approximate densities and threads finenesses, when subjected to stretching deformations, was investigated. These are raw fabrics (100% cotton) that should go through finishing and dyeing and/or printing stages by the end of production.

Breaking characteristics, breaking force and elongation at break, modulus of elasticity and work at rupture were analyzed as very important properties of the fabric considering that they directly determine the quality and utility value of the final product. At the same time, these parameters represent the starting point for defining the level of subsequent chemical treatments.

2. EXPERIMENTAL PART

Raw fabrics in linen, twill and atlas weave, made of 100% cotton yarns with close values for count and setting of warp and weft threads, were used in the research. The basic properties of the examined fabrics are shown in table 1.

Table 1: Nominal values of the basic properties of cotton fabrics

Yarn count (tex)		Yarn setting (cm^{-1})		Mass per unit area (g/m^2)	Weaves
Warp	**Weft**	**Warp**	**Weft**		
30	20	31	23	192	Linen
29	21	30	22	189	Twill
31	19	29	23	178	Atlas

The fabrics are woven under production conditions in the weaving mill, on a Picanol Omni 4P pneumatic loom (manufacturer Picanol, Belgium), loom speed 750 min^{-1}, shed forming cam mechanism, working width 1900 mm, profiled reed, number of harness 8, warp tension 1.5–2.5 kN. After weaving, the relaxation of the fabric is achieved in a relaxed state for 24 hours. After stabilization, the mechanical properties of the fabrics were checked.

Fabric testing methods:

- Breaking force *(F)* and elongation at break *(ε)*, according to the SRPS ISO 5081 standard.
- Work at rupture is obtained after integration of the deformation curve F–ε shown in the diagram of the same name with the help of the OriginPro program package.
- The modulus of elasticity, *E*, represents the ratio between the stress σ (N/mm^2) in the elastic region and the unit elongation ε (%). The modulus of elasticity was determined by the graphical method with the help of the mathematical software OriginPro, by drawing the dependence diagram $\sigma : \varepsilon$.

Each result shown in the paper is the mean value of 10 measurements. Also, statistical data for each measurement were analyzed, polynomial fitting and correlation analysis of deformation properties of fabrics was performed.

3. RESULTS AND DISCUSSION

Tables 2 and 3 show the results for breaking force and elongation at break of the analyzed cotton fabrics.

The measured values of the breaking force parameter in the linen weave in the warp direction have the highest mean numerical value of 201 N. Also, the same weave, in the weft direction, has the highest breaking force value of 158 N. The lowest values of this mechanical indicator have the cotton fabric in the atlas weave, in both directions, for the warp (190 N) and the weft (145 N).

The standard deviation (SD) and coefficient of variation (Cv) for the fabrics in all weaves have values that range within the range confirming the validity of the results.

Somewhat larger variations of these statistical data for the breaking force of fabrics in linen and atlas indicate that these results can be taken but with a certain amount of reserve and caution. It seems that there are a lot of latent stresses in the fabric, which are relaxed during the action of the breaking force, causing greater variations in the measurement results. As the fabrics have very similar yarn count and setting values, these differences in breaking force results come mainly from the weave. It should not forget the influence of the transverse threads, which take over a part of the resistance to the stretching force, that is, by wrapping the longitudinal threads, they increase the friction between the fibers of those threads, thereby strengthening them [6,7].

Table 2: Results of breaking force of cotton fabrics with different weaves

Statistical parameters	Breaking force, N					
	Linen		Twill		Atlas	
	Warp	Weft	Warp	Weft	Warp	Weft
Mean value, N	201	158	195	151	190	145
Standard deviation, SD, N	5.37	4.12	4.14	2.79	4.31	4.82
Coefficient of variation, Cv, %	2.67	2.61	2.11	1.85	2.27	3.32

According to Table 3, the elongation at break of fabrics in all weaves varies from 6.2 (warp direction, atlas weave) to 7.5% (weft direction, twill weave). The pattern in twill weave has the highest values for elongation at break, which is related to the interweaving structure of the warp and weft and the residual stresses in the fibers, i.e. the yarn. Statistical data additionally clarify the obtained measurement values of this examined parameter.

Table 3: Results of elongation at break of fabrics

Statistical parameters	Elongation at break, %					
	Linen		Twill		Atlas	
	Warp	Weft	Warp	Weft	Warp	Weft
Mean value, %	6.9	7.2	7.0	7.5	6.2	7.1
Standard deviation, SD, %	0.42	0.43	0.91	0.72	0.49	0.70
Coefficient of variation, Cv, %	6.11	5.98	13.04	9.66	7.90	9.86

Figures 1 show diagrams of dependence breaking force-elongation at break in the direction of the warp, i.e. weft. It is about the so-called deformation curves that explain the fabric's reaction to stretching.

At the beginning of stretching for both directions of the threads, all fabrics have a small increase in the breaking force with the increase in elongation, and later after 2.5% elongation there is a sudden increase in the breaking force from 20 to 200 N.

Table 4 shows the values of the modulus of elasticity of the used cotton fabrics by warp and weft. In a mathematical sense, the data were obtained from the equation $\sigma = E \times \varepsilon$, in which the modulus of elasticity is the coefficient of the direction of the linear part of the curve (slope), while the coefficient of determination, in all cases, was 1, which confirms the absolute functionality of the variables.

According to the results from the Table 4, it is observed that the fabric in the linen weave has the highest values for the modulus of elasticity in both directions, while the lowest values are registered for the cotton fabric in the twill weave, also in both directions.

This means that the largest applied force (stress) is necessary to deform the fabric in the linen weave compared to the fabrics in the other weaves, which coincides with the results of the other measured parameters.

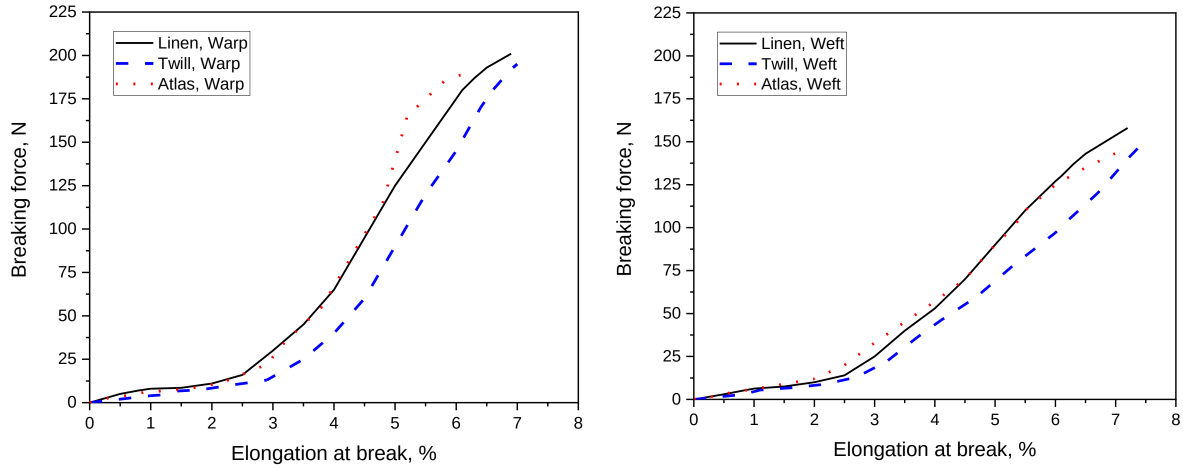

Fig. 1: Deformation curve of the analyzed fabrics in the warp and weft direction

Also, Table 4 shows the results of the work at rupture of cotton fabrics of different weaves, by warp and weft. Less work at rupture means less resistance of fabrics to external deformations, i.e. to stretch to rupture in this case. According to the results, the highest resistance to deformations was shown by the fabric in linen weave, while cotton fabrics in twill and atlas weaves have the lowest values of this parameter.

Table 4: Results of elongation at break of fabrics

Statistical parameters	Linen		Twill		Atlas	
	Warp	Weft	Warp	Weft	Warp	Weft
Modulus of elasticity, kPa	400	250	160	140	300	240
Work at rupture, J	1.48	1.26	1.20	1.12	1.15	1.22

Deformation curves after nonlinear fitting of the breaking force–elongation at break dependence are represented by diagrams in Figure 2. The procedure of fitting the experimental data was done, i.e. formulating the function $F(x)$ that approximates the unknown dependence of $f(x)$, so that the deviations of experimental values from computational estimates are small in a certain sense [6,7].

The diagrams in Figure 2 can also be called scatter diagrams, given that, in an obvious way, they provide a visual representation of whether or not there is dependence and interdependence between variables x and y, as well as its character and intensity.

Table 5 gives data related to the appearance of the equation of the fourth and fifth degree polynomial, which very well describes the breaking force-elongation at break relationship for each of the tested fabrics of different weaves, in the warp and weft direction. Based on these equations, the behavior of the same or similar fabrics in terms of mechanical characteristics can be predicted with sufficient reliability without practical measurement of breaking force and elongation at break.

A good measure of the adequacy of a polynomial model is confirmed by the coefficient of determination, R^2. In the specific case, it is stated that about 99% of the variability of the dependent variable can be explained by means of the analyzed independent variables.

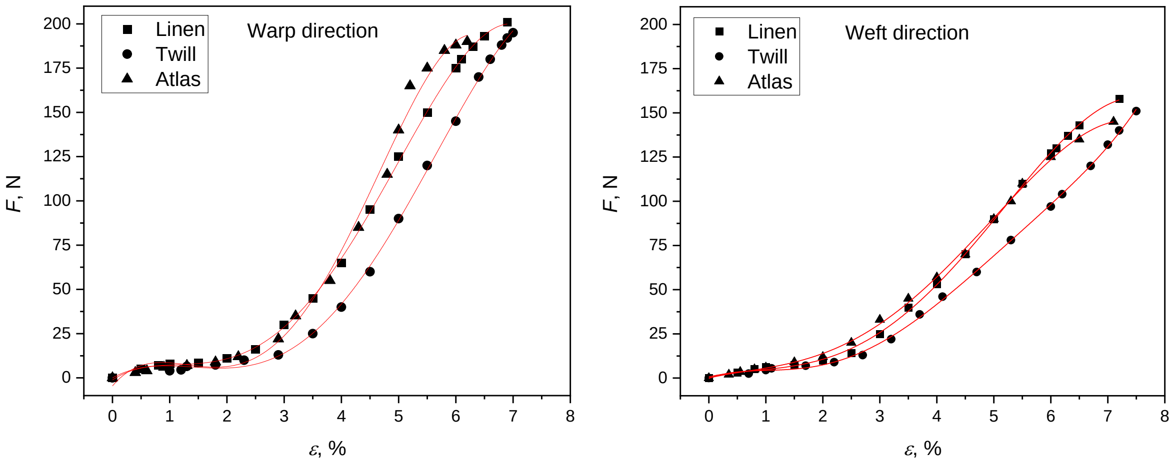

Fig. 2: Deformation curves after non-linear fitting in the warp and weft direction

Tab. 5: Polynomial equations of the second degree according to the fitting of deformation curves

Weaves		**A polynomial equations of the fourth and fifth degrees**	R^2
Linen	Warp	$F = -0.04 + 18.18 \cdot \varepsilon - 16.31 \cdot \varepsilon^2 + 5.94 \cdot \varepsilon^3 - 0.48 \cdot \varepsilon^4$	0,9998
	Weft	$F = 0.70 + 7.20 \cdot \varepsilon - 5.39 \cdot \varepsilon^2 + 2.57 \cdot \varepsilon^3 - 0.21 \cdot \varepsilon^4$	0.9996
Twill	Warp	$F = -1.18 + 21.25 \cdot \varepsilon - 18.38 \cdot \varepsilon^2 + 5.50 \cdot \varepsilon^3 - 0.39 \cdot \varepsilon^4$	0.9994
	Weft	$F = -0.21 + 12.33 \cdot \varepsilon - 12.79 \cdot \varepsilon^2 + 5.81 \cdot \varepsilon^3 - 0.86 \cdot \varepsilon^4 + 0.04 \cdot \varepsilon^5$	0.9995
Atlas	Warp	$F = -4.55 + 38.00 \cdot \varepsilon - 35.57 \cdot \varepsilon^2 + 11.59 \cdot \varepsilon^3 - 0.97 \cdot \varepsilon^4$	0.9952
	Weft	$F = 0.06 + 7.26 \cdot \varepsilon - 3.55 \cdot \varepsilon^2 + 2.05 \cdot \varepsilon^3 - 0.18 \cdot \varepsilon^4$	0.9992

Figure 3 shows a diagram that defines the correlation dependence of the results for the breaking force of the fabric in the fabric weave in the direction of the base determined according to experimental and modeled values. According to the appearance of the correlation curve, a high coverage of the experimental points is noticeable, the value of the correlation parameter according to Pearson (Pearson's r = 0.999) is close to 1, which confirms a strong connection and mutual dependence [7,8].

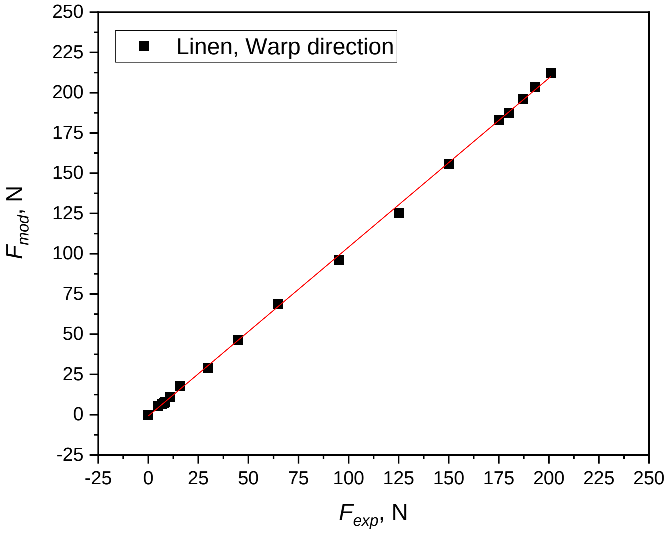

Fig. 3: Correlation of breaking forces of cotton fabric estimated by experimental and modeled values

5. CONCLUSIONS

The quality of the fabric itself is influenced by many factors, primarily the quality of the raw materials, the structure and constructive solution, the type of loom on which the fabric is made, the expertise of the workers, the organization of work, etc.

Based on the analysis of the deformation properties of three cotton fabrics with different weaves and very similar other characteristics, it can be concluded:

- The values of the breaking force of the fabric in the linen weave have the highest numerical value, while the cotton fabric in the atlas weave has the lowest values.
- The fabric in twill weave has the highest values for elongation at break, while the lowest values are present in the fabric in atlas weave.
- According to the results for the modulus of elasticity and the work at rupture, it is stated that the fabric in linen weave is the most resistant to external deformations, while the fabric in twill is the weakest.
- Deformation curves after non-linear fitting of the breaking force-elongation at break dependence are successfully described by polynomial equations of the second degree.
- Correlation analysis of the dependence between numerous values for breaking force from the experiment and the polynomial model showed that there are statistically significant correlations between these parameters.

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ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

RESEARCH ON THE TRADITIONAL CROCHETING TECHNIQUE IN THE MOLDOVAN COSTUME

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Abstract: *Folk songs, customs, traditions, national costumes are part of our history. They are priceless treasures that define us as nation. It is our duty to keep them sacred and pass them down from generation to generation. The work presents the results of the research of the techniques of ornamentation of handmade products, textiles, fabrics, leather and accessories from the area of Bessarabia. Special attention was paid to lace and the correlation of the crochet motifs with embroidery elements. Lace is a decorative element of the interior of the house, but also a garnishing element of the popular shirt. It is considered to be one of the oldest decoration techniques with considerable revival and appreciation in the 15th century when it is used to decorate royal and noble clothing. In the folk costume, lace is made with a crochet hook and a needle with cotton or silk thread. If the embroidery ornaments in the folk costume are in colors, then the lace is made in white. The study was carried out on the basis of the popular costume, the towels from the interwar period of the 20th century. The results of the use of information technologies in the preservation of these ornaments are also presented. The purpose of this study is to present the stages used in the identification and revitalization of the ornamentation techniques characteristic of our country, to identify the methodology of preserving the traditional ornaments used in the Republic of Moldova and to propose directions for further use.*

Key words: *ornamentation techniques, crocheting, digital library, embroidery, special software.*

1. INTRODUCTION

The national Moldovan costume is a vivid example of the unique creativity of folk craftsmen, an example of ancient customs, evidence of the deep interaction of the Moldovan ethnos with neighboring nations. [1] In the past, it was not accepted to copy the ornamental motifs from another person's costume, nor to alienate from community traditions. Each girl had to create her own festive costume, leaving the mark of local traditions and her aesthetic vision on it. The costume must correspond to the nature of the man, to harmonize with his outfit, with the color of his eyes and hair, his age and his place in society. [2] Traditionally, Moldovan national costumes were made of dense materials such as: wool, linen, hemp, cotton. The material of the suit reflected the well-being of the family. Moldavans of modest means used hemp fabrics, while the more affluent used linen or cotton. These types of textiles were made by women, under home conditions.

Specific to the folk costume is the chromatic element, characterized by sobriety and balance in the use of colors, in their harmonious combination, resulting in the achievement of tasteful coloristic effects and artistic refinement. The basic colors are: black, red, dark brown, blue, green and purple. The colors of the folk costume are characterized by harmony and freshness, the colors being combined in an aesthetic way.

The ornamentation of the Moldovan costume was directly related to the area where this people lived. Fertility of the soil, mild climate, rich harvests - everything was reflected in the ornamentation on the fabric. The ornamentation of textiles depends on several factors. The first important factor is the raw material used for beautification. The second factor is the technique of obtaining the ornaments. It is also necessary to take into account the function, thematic content or the meaning of the ornamental motifs. All these factors together make each genre of art correspond to specific decorative-artistic features. [2]

Over time, various ornamentation techniques were used in the decoration of Moldovan textiles, such as: embroidery, crocheting, weaving, artistic processing of leather and fur, etc. All of them signify certain actions, messages and events in the life of Moldovans, and throughout history they have allowed us to define ourselves as a people. Today, in the process of returning to traditional values, it is necessary to preserve and protect the diversity of ornamentation techniques, and to pass them on from generation to generation.

2. CROCHET TECHNIQUE IN THE REPUBLIC OF MOLDOVA

The museums of history and ethnography in the republic offer us a rich study material of the folk costume. The folk costume is one of the vestiges and true treasures of the nation that passes from century to century, enriches itself aesthetically and at the same time preserves its identity. Many studies are dedicated to the embroidery of the costume, the symbol and the graphics of the predominantly embroidered ornament. Covering a considerable part of the surface of the shirt, capturing attention either through the expression and aesthetics of the embroidered symbol, or through the abundance of ornamentation, or through the quite rich chromatic correlation proposed by the craftswoman, or through the refinement and delicacy of the combination of the types of embroidered stitches that in a shirt could exceed more than 5-8 sewing techniques/points [3, 4]. Embroidery is done with threads, colored beads, sequins. The embroidery thread could be made of linen, cotton, silk, wool, "stitched with wire" or metallized with gold, silver, etc. "A non-embroidered or "unstitched" shirt does not exist among the rural population of Moldova" - description made in 1817 by Francisc Graf von Karaczay. [4] The decor in the folk costume was significant and of symbolic importance.

The crocheted decorative elements are less reflected in the studies on the folk costume. Crocheted lace is used in abundance in towels, pillowcases, bed sheets, handkerchiefs, etc. All nominated products offered a decorative character to the interior of the house, with the crocheted elements placed in horizontal bands, sometimes repeated and bordered. If the embroidery, both in the popular costume and in the interior products, offered color, then we only find the lace in white, a color that was considered basic in the costume.

Crocheting is considered a rather archaic technique. The first accounts of lace used in clothing are attested in biblical writings. The spider's web, as well as the fisherman's web, are some of the simplest and first knots tied in a lace rhythm with a functional role in both cases. Lace is very widespread, used both in popular wear and in urban clothing. Vertiginous followers, in the use of lace in clothing and interior decoration, were the royal families and high-ranking boyars thanks to which the lace spread and evolved as a very complex and diverse aesthetic element.

Currently, hand-made lace is made using different tools such as: crochet, bobbins, simple and special needle, knitting needle, etc. tools that are mostly adapted to the techniques and contribute to the formation of the openwork aspect of the lace. But, during the period of appearance in the 15th-16th century and later, a lace was called authentic if it was made with a needle or using special devices called bobbins. Initially, the lace was made from linen threads and featured a geometric ornament with a jagged edge that was assembled at the end of the garment. Along with the appreciation by the social strata and consequently the expansion of this decoration technique, the lace is adapted to the traditions and culture of the place where it is born. That is why today the techniques for making lace, but also lace itself, are named after the places of development and appearance. In this way we distinguish "Brussels", "Valenciennes", "Chantilly", "Argentan", "Alenson", "Tulle", Venetian lace, "Mecheln" lace, "Galich" lace, "Torzh", " Yelets", "Vologda", etc.

The problem of the popular costume is more and more frequently included in the list of various discussions, either in problems of designing a new product, or in international identification, or in product advertising with an identification and localization message, or in the search for new technological solutions, novel, aesthetically argued, processing of the clothing product. Passed through time and argued through the reinterpretation of generations, the costume and any other popular products prove to be permanently the most appropriate sources of inspiration for new approaches to contemporary products. [5, 6] In the Museums of History and Ethnography of the republic are kept samples of lace (fig.1) made by hand in the family by housewives for various ritual needs, but also for everyday use. Ornamental motifs crocheted on household products are the tree of life (fig. 1a, b), the rooster, birds and animals (fig. 1b), rhombuses, etc. [7] The lace is mainly made with a crochet hook and with quality cotton thread, but it is also made with a needle. The lace making technique is one "of the earliest forms, it was known as Opus filatorium or, in the Middle Ages, as Spider Work [8]" later 19th century Point Conte.

a) b) c) d)

Fig. 1: Vegetal, floral, animal, geometric motifs in the lace of towels and folk costumes, museum samples, from the interwar period of the 20th century; a)- bed sheet, Ungheni, b)- bed sheet, Nisporeni, c)-the end of the shirt sleeve Ungheni, d)- towel, Nisporeni

In the folk costume from the Republic of Moldova, from a decorative point of view, lace has more of a border role. It is used for the decoration of the poncho type shirt and Ie. The lace in the suit matched the embroidery decoration, therefore it was distinguished by the more geometric motif of the ornament and the final product endings (fig. 1c) by a jagged line, also having the role of a soft accent. It could be made with a needle or crochet in white silk or cotton threads of a special refinement in the case of the crease area „*încreţ*". The motif of the ornament used in the lace of the shirt was a vegetable one, the rose, the basil flower, the star and many other serpentine or jagged lines framed in the rhythm of the openwork squares of the lace are frequently found. Following the analysis of several popular costumes kept in the museum archive, as well as photographs from the end of the 19th century and the beginning of the 20th century, it was found that the lace ornament is not so frequent, but present and preserved in the characteristics of the ancient lace.

3. PRESERVING TRADITIONAL ORNAMENTS USING INFORMATION TECHNOLOGIES

The process of preserving and transmitting ornamentation techniques is a complex one. It takes time to collect the ornamentation techniques characteristic of our people. It is also necessary to identify and study various specialized software that will allow the archiving of these ornaments. And finally, the obtained results must be verified, in order not to transmit a erroneous information.

Figure 2 shows the stages used from the identification of the ornamentation techniques characteristic of our country to the presentation of directions for further utilization, using various specialized software.

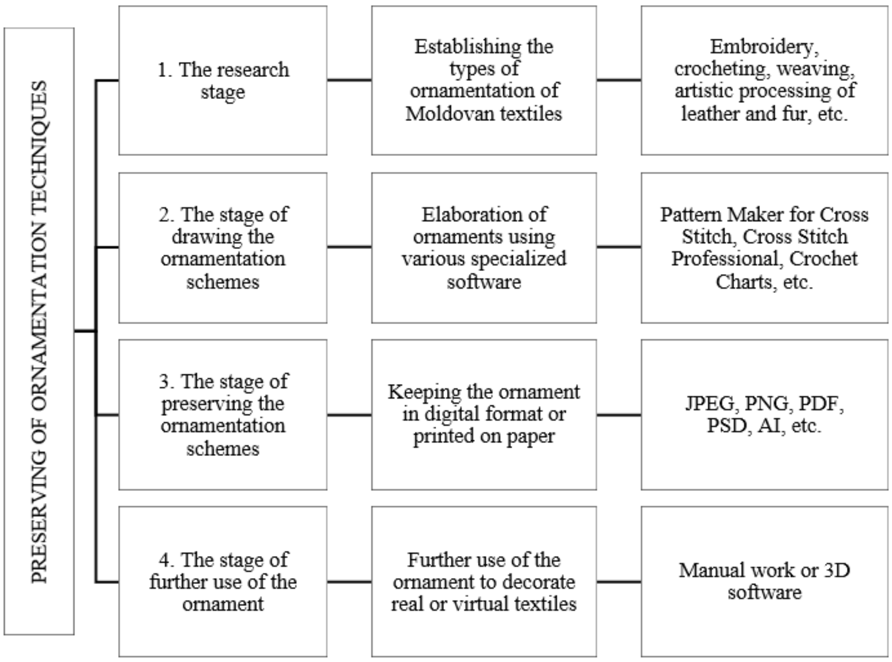

Fig. 2: The stages used since the preserving of ornamentation techniques

An important stage of this process is the research stage. Here, the types of ornamentation of Moldovan textiles are established. For this stage, trips were made to different museums in the country. There, we could admire various articles of clothing and textiles with different ornamentation techniques. In the second stage of this process, various specialized software is used that allow us to develop the ornaments automatically, or by successively drawing the seams. Currently, there are a large number of software, and selecting the best one depends on the ornamentation technique and the user's skills.

The stage of preserving the ornaments can be divided according to necessity. If we plan to use a technique of manual ornamentation, then the scheme must be printed on paper, which is then kept in the appropriate way. But the digital preservation method is much more secure.

In the fourth stage, further directions for the use of ornaments are proposed. Two ways of use were identified. The first way is to use the schemes in jpg format. This method can be used to decorate clothing, accessories, home textiles and other. The second way is to use schemes in png format, to create virtual collections.

Figure 3 shows an example in which all these stages can be identified.

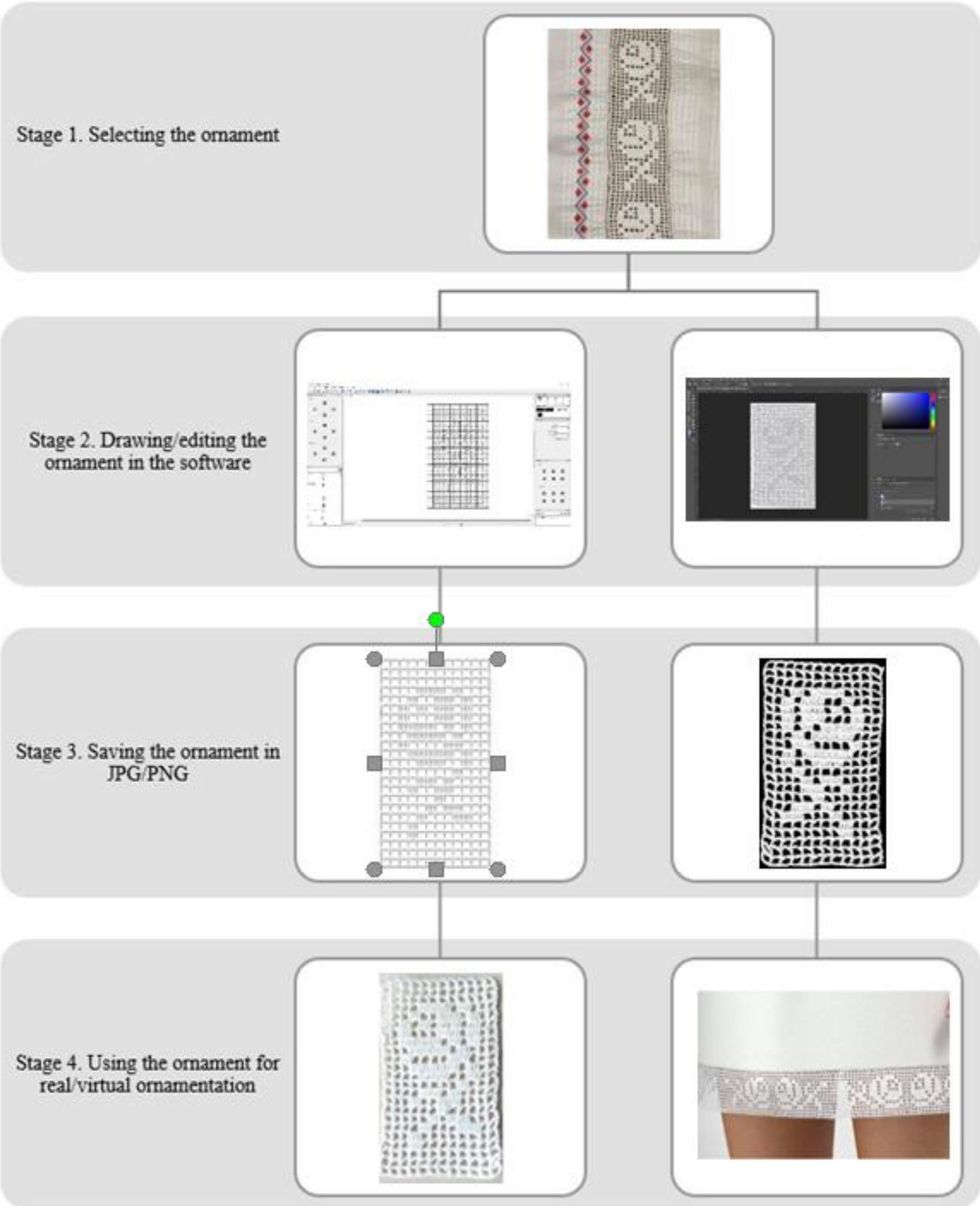

Fig. 3: The working example of a crochet ornament

4. CONCLUSIONS

The problem that this work solves consists in the analysis of the crocheting technique used in the Republic of Moldova. Also, various methods of preserving the traditional ornamentation techniques used in our country were identified and experimented. The identified stages provide the necessary information to understand the complexity of the preservation process of these techniques.

These identified stages allow us to:

- create databases with various ornaments that can be used as needed;
- diversify of the assortment of real textiles, using deciphering schemes;
- create and decorate virtual products;
- promote cultural heritage values.

After this study I noticed:

- the lace decoration is made in white colors with the help of a crochet hook or a needle in the "shabac" technique with white silk thread;
- the lace is crocheted in various motifs: vegetal, floral, geometrized, all of protective symbolic importance with decorative-artistic features specific to the geographical area and ethnic cultural space identical to the embroidery or in correlation with it. Namely: the rose, the grape vines with leaves, the rooster, rhombuses, the basil flower, the motif of the eight-pointed star, etc.
- the graphics of the ornamental elements of the lace made with the help of a crochet or a needle mainly fall into the rhythm of the 0,5x0,5 cm squares, giving the motifs a geometric character of stylization. The width of the lace trim in popular wear varied from 0,5-0,7 cm to 4,0-5,0 cm.
- in the lace decoration made with the needle in the "shabac" technique with white silk thread, the following was made: the crease, the end of the sleeve and the end of the shirt. The same lines were decorated with crocheted lace. The lace is assembled at the end of the shirt.

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ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

DEFORMATION BEHAVIOR OF CONDUCTIVE TEXTILE FABRICS

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Abstract: *Conductive textiles play a key role in making highly specialized clothing. While clothing made of conductive fabrics can experience mechanical stress during wearing, this paper presents a comparative study of the deformation behaviour of two conductive fabrics (knitted and woven fabrics). Based on the physical and mechanical tests and analysis, we calculated the anisotropy and Young modulus for both fabrics and also we simulated their wearing behaviour of them using a pattern design software (PDS) from OPTITEX.*
Both values were compared with the bending behaviour simulation on a human avatar using PDS-3D. The map of the simulated bending stress reveals the high peaks at elbows, hips, knees, thoracic and armpit areas. All the highest values obtained by simulation are lower than the calculated ones, which means that at maximum stress the fabrics will not be damaged.

Keywords: *Conductive fabrics, anisotropy, stress, deformation, simulation, pattern design software*

1. INTRODUCTION

The field of conductive fabrics is rapidly evolving, and new research is being conducted to explore the use of these specialized fabrics in creating specialized clothing with high comfort [1]. These materials can conduct electricity and can be used in a wide range of applications such as wearable technology [2], smart textiles [3], electromagnetic shielding [4], and electronic devices [5]. Researchers are exploring new materials and techniques for incorporating conductive materials into fabrics that are comfortable to wear for extended periods, and that can withstand stretching, bending, and washing without losing their conductivity or other properties [6]. As these technologies continue to evolve, we can expect to see more and more specialized clothing that takes advantage of the benefits of conductive fabrics. Conductive fabrics are fabrics that have been specially designed to conduct electricity, often using metallic fibers or coatings [7, 8].

Clothing made of conductive fabrics can experience mechanical stress during wearing, which can impact the electrical properties of the fabric. The wearing behavior of conductive fabrics depends on several factors, including the type of fibers or coatings used, the weave of the fabric, and the intended application [9]. In general, conductive fabrics can be quite durable and resistant to wear and tear, especially when compared to traditional fabrics. However, they can still experience some wear over time, especially if they are subjected to frequent use or stress [10]. One potential issue with conductive fabrics is that the conductive content can become damaged or degraded over time, leading to a loss of conductivity or other performance issues. This can happen due to factors such as exposure to moisture, high temperatures, or mechanical stress [11]. To minimize wear and tear on conductive fabrics, it is important to follow the manufacturer's guidelines for care and maintenance [12, 13]. Understanding the mechanical behavior of conductive fabrics is important for designing and engineering wearable electronics and smart textiles, where the fabrics are often subjected to a range of mechanical deformations during use [14].

Thus, in this paper, the mechanical behavior of two textile structures is presented and evaluated: a woven and a knitted structure, intended for professional underwear. Both structures have conductive textile threads in their composition. For the accuracy of the results, the values of the mechanical characteristics, obtained following the requests of the conductive textile materials, were compared with the simulation results with the Pattern Design Software (PDS) from OPTITEX.

2. MATERIALS AND METHOD

For the experiments, two different types of conductive textile yarns, with linear resistance of close values, were used, with the help of which two plain textile structures (woven and knitted fabrics), through classic/conventional technologies within INCDTP Bucharest.

The SEM and EDS analyses of the wires were carried out on the Auriga model workstation produced by Carl Zeiss SMT Germany FESEM FIB with field emission source with Gemini column for the electron beam. The SESI secondary electron detector of the Everhart Thomley type with the Faraday cup in the sample chamber was used at the acceleration voltage of 5 kV for sample visualization and 10 kV for EDS spectroscopy, as well as the energy dispersive spectrometer model X-MaxN with the acquisition software and Aztec processing.

The physical-mechanical characteristics of the analyzed textile structures highlighted: breaking force (N) and elongation at break (%), tear resistance (N), resistance to deformation (kPa), and deformation. Young's formula was applied to calculate the modulus of elasticity (N/cm^2). With these data, the anisotropy was calculated for the two structures.

For the simulation of the mechanical behaviour in dynamic conditions of the analyzed conductive textile structures, Optitex PDS was used, a 3D design/modelling/simulation software of personalized clothing items using human avatars and virtual models. Any change in the pattern size table is automatically transferred to the 3D virtual model.

3. RESULTS AND DISCUSSIONS

Table 1 shows the main characteristics of the conductive yarns used to make textile structures.

Aspects of the longitudinal sections of the yarns and the EDX diagrams highlight the main compositional specific elements (see. Fig. 1).

Table 1: Conductive yarns characteristics

No.	Type of conductive yarn	Fineness, dtex	Apparent diameter, μm	Linear electrical resistance, Ω/m
1.	INNOX/PES (aWv)	200X2	273	220
2.	STATEX Ag/PES (bKt)	296	228	200

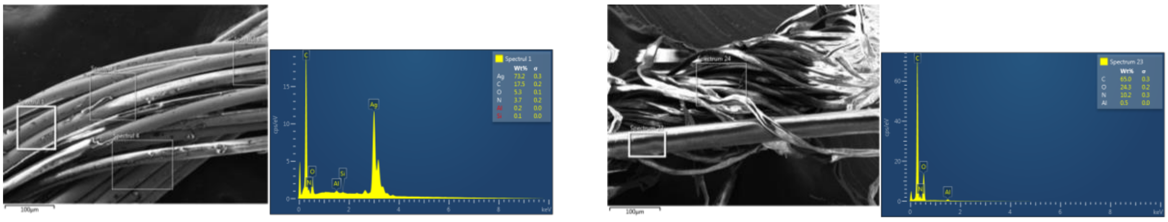

Fig. 1: SEM/EDX: a) STATEX Ag/PES yarn; b) INNOX/PES yarn

The woven structure **-** aWv (Fig. 2) and the knitted structure **-** bKt (Fig. 3) were subjected to mechanical tensile stresses, and the average values of the breaking force and elongation at break in the two orthogonal directions were recorded.

Fig.2: Woven fabric – aWv

Fig. 3: Knitted fabric - bKt

In the case of aWv, the average breaking force in the weft direction is about 37% of the average breaking force in the warp direction. In the case of bKt, the difference is smaller, the average breaking force in the horizontal direction being only ~54% of that in the vertical direction. The value of the average elongation at break, inversely proportional to the breaking force, in the case of aWv, is ~45.7% of that in the direction of the beam, while in the case of bKt, the value in the vertical direction is ~55% of that in the horizontal direction. It is found that the deformation resistance values (KPa) of bKt are ~51% lower than those of aWv, with the relative deformation values (mm) close (Table 2).

Table 2: Conductive woven and knitted fabrics.

Characteristics/Variant		aWv	bKt
Mass, g/m^2		151	115
Length of metallic yarn, cm/10 cm		10,5	35
Density, nr./10cm	H	75	280
	V	40 (metallic yarn)	46 (metallic yarn)
		50 (cotton yarn)	92 (cotton yarn)
Breaking strength, N	H	431,54	1665,81
	V	234,40	610,16
Elongation at break, %	H	94,14	32,19
	V	171,64	14,88
Thickness, mm		0,44	0,96
Deformation resistance	KPa	303,1	586,35
	mm	36,7	32,1
Tear resistance, N	H (Wa)	31,86	76,57
	V (Wf)	55,68	88,34
Water vapor permeability, %		29,9	21,5
Air permeability, l/m^2/s		307	5241

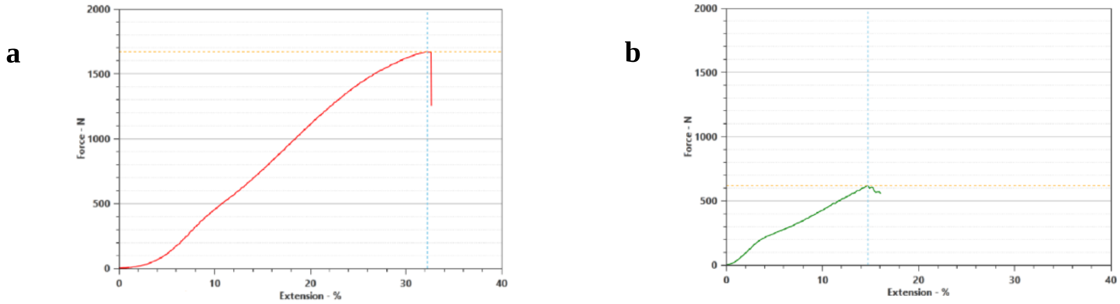

Fig. 4: Stretching behavior - aWv: a): warp direction; b): weft direction

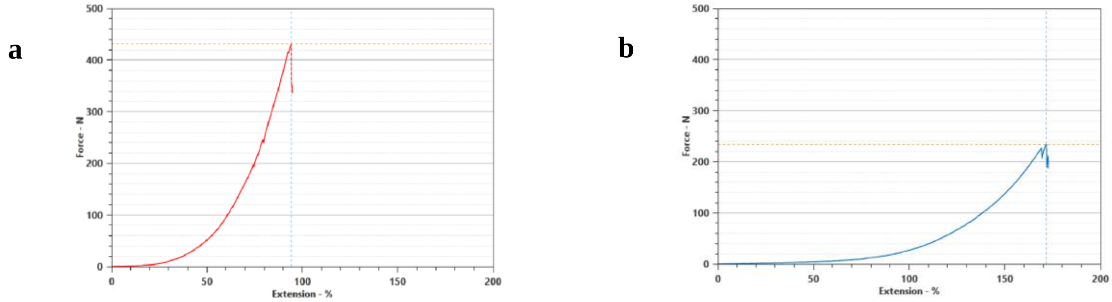

Fig. 5: Stretching behavior - bKt: a): vertical direction; b): horizontal direction

For the structures under analysis, the modulus of elasticity (Young's) was calculated as a measure of the stiffness of a material that describes the relationship between stress and strain in the material.

Table 3: Conductive woven and knitted fabrics

Variants		Force, N	L_0, cm	L_1, cm	ΔL	A, cm^2	Thickness, cm	Young modulus		Anisotropy
								N/cm^2	gf/cm	
aWv	H	200	20	20,6	0,6	202	0,044	16,6	1733,5	0,83
	V	100	20	21,0	1,0	201	0,044	20,0	2039,5	
bKt	H	80	20	21,6	11,6	204,8	0,096	0,766	77,36	2,89
	V	65	20	44,0	24	204,8	0,096	0,265	26,81	

To visualize and confirm the degree of deformation of the aWv and bKt structures during banding of the arms and legs, two comparative maps were selected: one map showing the simulated deformation in the upper area (fig 6) and one in the lower area (fig. 7). In the case of both structures, the simulation of mechanical stress during bending, on the avatar reveals areas of maximum stress in certain anatomical topographic regions:

- the cervical and thoracic area, including elbows breasts, armpits, and shoulders (upper area) (fig 6);
- the legs areas, including hips, knees, and calves (lower area) (fig. 7).

For a more accurate estimation of the stress behavior, the previously obtained values of strength and elongation of the material and approximate values for bending and shearing stress, which was estimated and selected from a proprietary database were used.

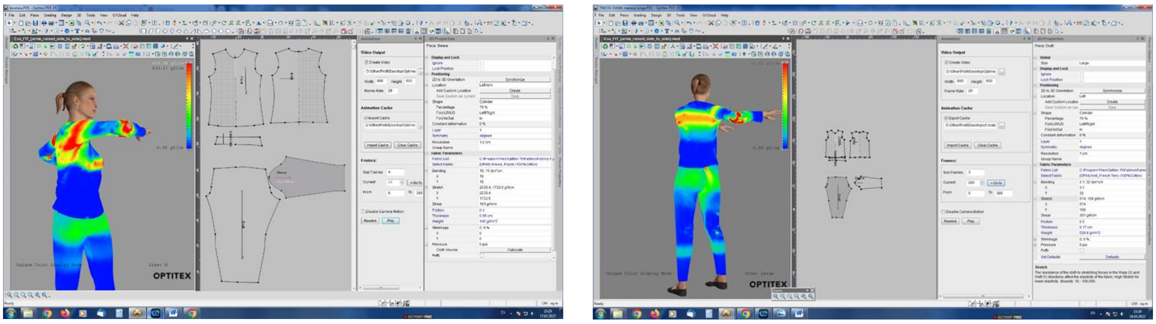

Fig. 6: Upper zone mechanical stress (red areas – maximum effort): a) aWv; b) bKt

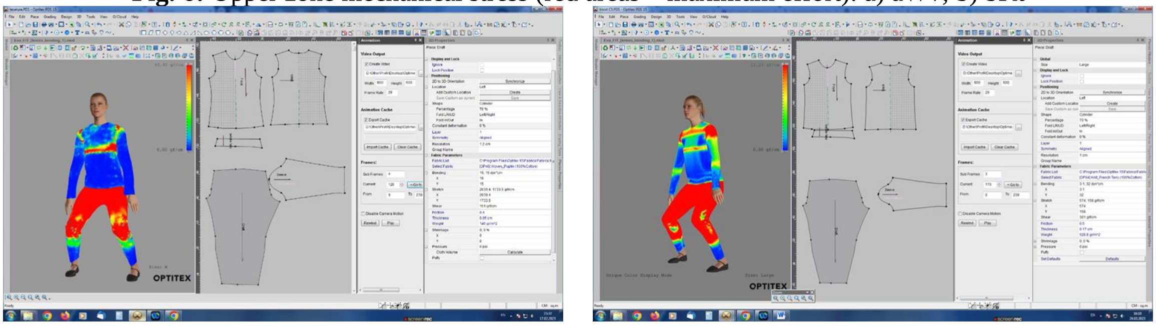

Fig. 7: Mechanical stress lower area (red areas – maximum effort): a) aWv; b) bKt

It is estimated that in the lower body area, the stress at exertion is much higher than in the upper area, according to figures 6 and 7. According to Figures 6 and 7, any variation in stress, during wear, appears colored other than blue on the dressed avatar. The higher the stress, the closer the colors of the respective areas are to orange. The maximum stress on the avatar map is colored in red. While a piece of professional underwear equipment for military use is desired to be developed using the two fabrics, both functionality, and comfort have to be high.

Comparing the upper and lower areas for both simulations shows that the widest red areas are presented at lower areas for both textile fabrics. Comparing the two situations and lower areas, higher stress was reported for the woven structure, which means an adjustment of the size in critical areas has to be done. Anyway, the maximum values of the stress obtained by simulation are lower than the calculated young modulus in both situations. In the case of aWv, the maximum stress obtained by human avatar simulation is ~4 times lower than the calculated one, while in the case of bKt, the maximum simulated stress is ~2 times lower.

5. CONCLUSIONS

The paper presents a comparative analysis of the wearing behavior of two textile conductive fabrics, designed to be used for professional underwear use in the military area. The physical and mechanical characteristics of the fabrics were used to calculate the anisotropy and Young modulus. Both values were compared with the bending behavior simulation on a human avatar using PDS 3D software. The map of the simulated bending stress reveals the high peaks at elbows, hips, knees, thoracic, and armpit areas. All the highest values obtained by simulation are lower than the calculated ones, which means that at maximum stress the fabrics will not be damaged.

ACKNOWLEDGEMENTS

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ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

TEXTILE PATTERNS FOR INTERIOR DESIGN WITH THREE-DIMENSIONAL SPIRALS

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Abstract: *Three-dimensional (3D) spirals are fascinating geometric shapes that are used in a variety of applications, such as textile fabric pattern and texture design, architecture, art, and engineering. In this paper, design of patterns using three-dimensional spirals are explored. The work began by discussing the mathematical properties of spirals and their applications. Then, several techniques for designing textile patterns are presented, including the use computer algorithms. Finally, examples of patterns that have been designed using spirals are presented. A comparative analysis was made with available literary sources. Guidelines for applying the obtained results in practice and guidelines for continuing this development are proposed.*

Keywords: *Pattern making, Interior design, Spiral, Data analysis, Color properties, Contemporary design*

1. INTRODUCTION

The rapid change in fashion styles and trends, diverse models and modern consumer demands, innovative materials, expect manufacturers to react quickly and present on the market up-to-date, beautiful and attractive fashion products. As for the variety of products, when creating new models in the interior, the designer must take into account the style and diverse preferences of consumers. The individuality of the furniture in the home is the main emphasis on which the user bases his decision, and in other cases, after he likes a given shape, the color is one of the main elements in forming his decision.

Using modern information and communication technologies (ICT), designers can promote their products and services worldwide [1]. ICT is also successfully used in the design of textile patterns itself. Computer-generated forms are distinguished by the fact that they can be obtained through easy-to-understand and use algorithms [2]. Software tools facilitate the process of creating geometric shapes and combining them with a variety of colors. In the majority of available publications in this field, these geometric shapes are presented through their mathematical descriptions [3], [4]. A major disadvantage of published software tools is that they offer the generation of a limited set of shapes.

Spirals are shapes that are ubiquitous in nature and have long fascinated humans. From the spiral patterns found in seashells to the spiral galaxies in the universe, spirals are figures of beautiful and mesmerizing shapes. In recent years, designers and artists have been exploring the use of 3D spirals in their work [5]. 3D spirals are more complex than their 2D counterparts and offer a greater range of possibilities for designing textile patterns.

A 3D spiral is a curve that starts at a point and moves away from it while rotating around an axis. The shape of a helix is determined by its pitch, which is the distance the helix moves away from the point of revolution, and its radius, which is the distance from the center to a point on the helix curve [6]. 3D spirals are widely used in various fields. In architecture, 3D spirals have been used to create unique and visually stunning buildings [7]. In art, 3D spirals are used to create sculptures and installations that evoke the viewer's sense of space and movement. In engineering, 3D spirals are used to design complex structures, such as bridges and towers, that can withstand extreme forces [8].

There are various techniques for designing patterns for 3D spiral patterns. One approach is to use mathematical formulas to generate a spiral shape and then manipulate the shape [9], [10]. Another approach is to use computer algorithms to generate the spiral shape and then apply various transformations, such as scaling and rotation [11]. Last but not least, physical models can also be used to experiment with different spiral shapes and patterns [12].

There are a number of examples of models that have been designed using 3D spirals [13]. In jewelry, 3D spirals are used to create intricate and delicate designs that are both beautiful and functional. In textiles, 3D spirals are used to create fabrics with unique textures and patterns. In sculpture, 3D spirals are used to create large-scale installations that interact with the surrounding environment.

There are known sources in the literature [14] that cover the technical aspects of creating broken and continuous spirals using the Blender 3D software. Step-by-step instructions are provided on how to create a basic shape spiral for a cylindrical object and how its radius, object density and repeating pattern size can be changed.

In his book, Rosen [15], discusses the technical aspects of developing precise professional garments. The author presents the tools, concepts, procedures and principles of professional creation of planar models using base curves.

The book by Browning et al. [16], covers the benefits and principles of biophilic design and presents the connections between nature, human biology and interior design. The book provides insight into the role of nature in design and may inspire new ideas for incorporating organic shapes and patterns into fashion and interior design.

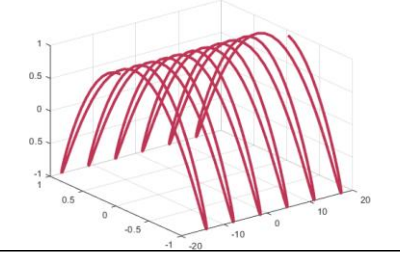
A major drawback that can be pointed out in the available literature is that solutions with specialized software products are offered for the creation of three-dimensional helices. This type of software is complex and requires considerable time to learn and master. This can slow down the textile pattern design process to some extent.It is necessary to make a deeper analysis of the known methods and approaches used so far to create tridimensional spirals, which will lead to improvement and facilitation of the process of creating modern textile patterns, with the aim of implementation in automated systems to help to the designers.

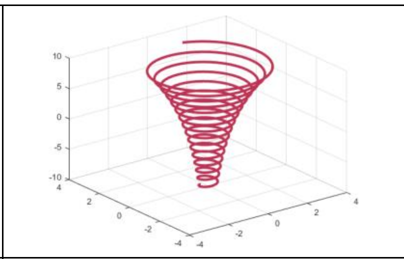
The purpose of this article is to explore the design of textile patterns using 3D spirals and demonstrate examples of their use.

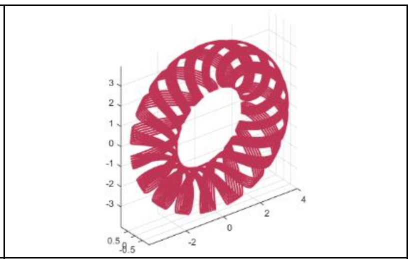
2. MATERIAL AND METHODS

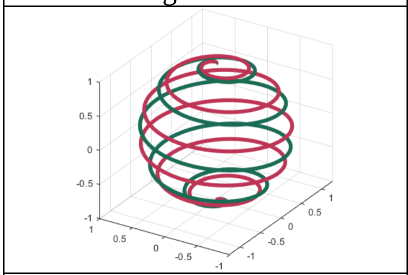
Algorithms and procedures for creating trimeric helices presented in the available literature sources were used [7], [12], [17]. These algorithms are presented in Appendix A. The algorithms are implemented in the Matlab 2017b software system (The Mathworks Inc., Natick, MA, USA.).

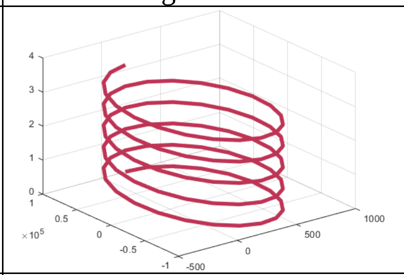
Figure 1 shows in general view six different three-dimensional spirals that are realized. The spiral obtained by Algorithm 1 is alternating semicircles. The second spiral has an increasing radius along the horizontal axis and increasing in height. The third spiral is a "doughnut" type. The fourth is two spirals wound around a sphere. The fifth spiral has the same radius for all turns and increases in height. The sixth helix imitates a ship's sail under the pressure of the wind.


Algorithm 1


Algorithm 2


Algorithm 3


Algorithm 4


Algorithm 5

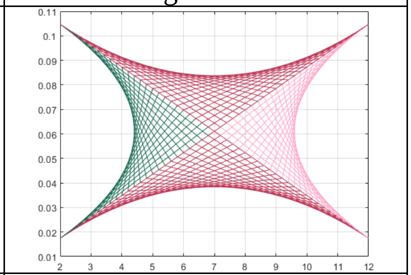

Algorithm 6

Fig. 1. 3D spirals generated with algorithms

The palettes, presented by Nisha [2022] were used. These are related to combining the Pantone color of 2023 with other suitable colors. The colors used are presented in Table 1. The values of the color components from the RGB and Lab color models are indicated. The first color is Pantone's for 2023 – Viva magenta, followed by light pink and green. Purple and yellow follow. Finally, they are beige, brown and pink.

Table 1. Colors used in this study

Color component / Color number	R	G	B	L	a	b
C1	186	38	73	41,70	58,96	17,46
C2	255	167	202	77,97	37,08	-4,34
C3	26	107	84	40,20	-29,89	6,08
C4	173	147	180	64,20	15,76	-13,58
C5	234	224	51	87,51	-14,42	78,43
C6	206	194	174	78,90	0,88	11,58
C7	105	64	38	31,37	15,02	23,17
C8	173	147	180	64,20	15,76	-13,59

Examples of application of the developed patterns in the field of interior design are offered. For this purpose, the online applications “Bags of Love” (https://www.bagsoflove.co.uk accessed 4 April 2023) and “Digital Fabrics” (https://www.digitalfabrics.com.au accessed 4 April 2023) were used.

3. RESULTS AND DISCUSSION

3.1. Results

Figure 2 shows the realized motifs with 3D spirals. Motif M1 is obtained by Algorithm 3, it combines color C1 and C6. Motif M2 obtained by Algorithm 4 combines three colors C1, C4 and C6. Model M3 uses a spiral generated with Algorithm 6. It combines the colors C1, C2 and C3. Model M4 is created as a mirror copy of the spiral generated with Algorithm 2. Thus, a figure was obtained, representing an increase in the diameter of the spirals from the center of the motif up and from the center down. Two colors C1 and C6 are combined. Motif M5 is realized, with the spiral obtained with Algorithm 5 presented in a vertical winding direction and below it, rotated by 90 degrees. The colors C1 and C8 are combined.

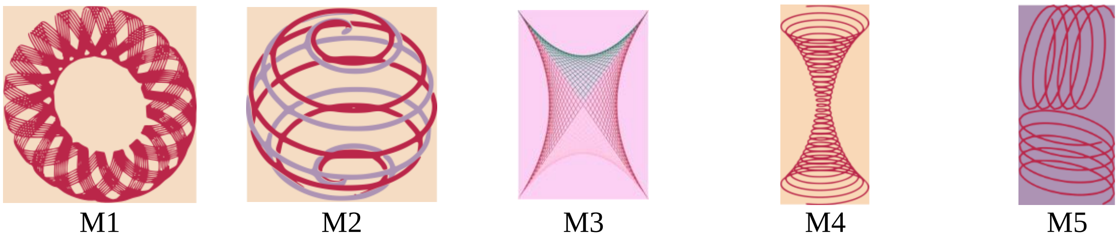


Fig. 2. Motifs (M) with 3D spirals

Figure 3 shows an example of the application of a three-dimensional spiral of the "doughnut" type, obtained by Algorithm 3, in the cladding of chairs, stools and a folding table. When implementing the fabric design, the element is rotated in arbitrary directions. The interior of the room includes a cozy sitting area with two comfortable chairs, modern stools and an elegant table. The chairs have a classic design, without armrests and a high back. The stools are a unique piece with a contemporary design, featuring a sculptural, geometric shape and a seat upholstered in the same fabric design that provides a stunning complement to the chairs. The folding table is a minimalist piece with a rectangular shape with a polished wooden frame and a top lined with the proposed fabric design, which adds a touch of sophistication to the room. The table is suitable for placing books, magazines or drinks and is at a comfortable height for both chairs and stools. The overall effect of these elements in the room is a harmonious balance of comfort, style and functionality. The seating area invites you to relax and rest, while the table provides a functional surface for everyday use.

Fig. 3. Interior design with 3D spiral obtained from Algorithm 3

Figure 4 shows an example of the application of three-dimensional spirals of the type described around a sphere, obtained by Algorithm 4, in the upholstery of a sofa. The proposed sofa model is a modern, L-shaped piece of furniture with an elegant, minimalist design. It comfortably accommodates up to 3-4 people. The sofa is upholstered with a luxurious beige damask, decorated with the motifs of the proposed spiral, which gives a touch of sophistication to the room. The seat back has firm and supportive sides, providing a comfortable sitting experience. The sofa has square shaped armrests that provide a comfortable place to rest your hands or a cup of coffee. The legs are made of sturdy metal and finished in a matte gold color, adding a contemporary look to the sofa. Overall, the design of the living room sofa is stylish, comfortable and suitable for entertaining guests or relaxing with the family.

Fig. 4. Interior design with 3D spirals obtained from Algorithm 4

Figure 5 shows an example of an application of three-dimensional sphere-type spirals obtained by Algorithms 2, 5, and 6. The pillows have an attractive design that includes spiral motifs, each with a unique repeat. The first pillow has a spiral motif that mimics a ship's sail, with a bold, curved shape that evokes the feeling of a sea adventure. The second pillow has a rising spiral motif obtained by repeat of type half drop, which creates a sense of depth and movement. The third cushion includes two non-intersecting spirals at 90 degrees to each other. They create a mesmerizing geometric pattern. Each pillow has a soft texture and is covered in a neutral-toned fabric that complements the intricate design. Cushions are suitable for adding visual impact and texture to sofas and chairs, and spiral patterns create a sense of energy and dynamism in the room. The cushions on offer are a beautiful and unique addition to any home decor.

Fig. 5. Interior design with 3D spirals obtained from Algorithms 2, 5 and 6

3.2. Discussion

Designing 3D spiral models is an interesting and complex process that requires a thorough understanding of mathematical principles and design techniques. Spirals have fascinated mathematicians and artists alike for centuries, and their application in design is prevalent in fields as diverse as architecture, engineering, and art [7], [8].

Spirals are characterized by their mathematical properties, such as the constant distance between each turn of the spiral, the angle of the spiral, and the shape of the curve itself. These properties are critical when designing spiral patterns, and designers should have a clear understanding of them before creating any patterns. Through the presented algorithms for creating spirals and their implementation in a programming environment, this work complements the results of Browning et al. [16] who point out that through spirals a connection can be made between nature, human biology and interior design.

Designers can use mathematical formulas and the computer algorithms proposed in this development to create complex spiral patterns. These techniques can be used to build complex patterns of patterns that would be difficult to realize by hand [15]. The computer algorithms proposed here can be used to generate patterns based on predefined parameters or to randomly generate patterns of elements from which to make patterns for interior design.

Designing 3D spiral patterns requires skill and creativity. The presented comparative analysis with available literature sources can help designers learn from past designs and incorporate new ideas into their work. Guidelines for applying the results obtained in practice can also help designers to create models that are both beautiful and functional.

4. CONCLUSION

In this paper, a study is made on the design of textile pattern patterns using 3D spirals. The mathematical properties of spirals, their applications, and several techniques for designing textile patterns with them are discussed. Also shown are examples of pattern patterns that are designed using 3D spirals. The use of spirals in textile pattern design offers a wide range of possibilities and is a fascinating area of research for designers and artists alike.

Designing 3D spiral models is a fascinating and challenging process that requires an understanding of mathematical and algorithmic design principles and techniques. By using mathematical formulas, computer algorithms to create three-dimensional spirals, designers can create complex patterns of textile patterns that are both beautiful and functional. Guidelines for applying these results in practice and continuing developments in this area can help designers improve their skills and create even more complex and unique models.

Appendix A. Algorithms for 3D spirals

x = -6*pi:0.1: 6*pi;
y = sin(x);
z = cos(2*x);
plot3(x, y, z,'g','linewidth',3);
	t = linspace(-10,10,1000);
	xt = exp(-t./10).*sin(5*t);
	yt = exp(-t./10).*cos(5*t);
	plot3(xt,yt,-t,'linewidth',3);
		t = 0:pi/500:40*pi;
		xt = (3 + cos(sqrt(32)*t)).*cos(t);
		yt = sin(sqrt(32) * t);
		zt = (3 + cos(sqrt(32)*t)).*sin(t);
		plot3(xt,-yt,-zt,'linewidth',2)

Algorithm 1	Algorithm 2	Algorithm 3

t = 0:pi/500:pi;
xt1 = sin(t).*cos(10*t);
yt1 = sin(t).*sin(10*t);
	a=200; b=200; r=50
	t = 0:pi/10:10*pi;
	st = a+r*sin(t);
		angle=0.5; lower = 2;
		upper = 12;
		stepvalue = 0.2;

zt1 = cos(t);
xt2 = sin(t).*cos(12*t);
yt2 = sin(t).*sin(12*t);
zt2 = cos(t);
plot3(xt1,yt1,zt1,xt2,yt2,zt2,'linewidth',6)
	ct = b*r*cos(t);
	plot3(st,ct,t/10,'g','linewidth',6)
		lastindex = (upper-lower) * (1/stepvalue) + 1;
		mid = ceil(lastindex/2);
		x = [lower:stepvalue:upper];
		line1 = tand(angle)*x;
		line2 = tand(180-angle)*x + line1(lastindex)+line1(1);
		plot(x,line1,x,line2);
		for i = 1:(mid-1)
		hold all
		plot([x(i),x(mid+i)],[line1(i),line2(mid+i)]);
		hold all
		plot([x(i),x(mid-i)],[line1(i),line2(mid-i)]);
		hold all
		plot([x((mid*2)-i),x(mid+i)],[line1((mid*2)-i),line2(mid+i)]);
		hold all
		plot([x((mid*2)-i),x(mid-i)],[line1((mid*2)-i),line2(mid-i)]);
		end

Algorithm 4	Algorithm 5	Algorithm 6

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ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

MYCELIUM BIO-COMPOSITES: THE FUTURE OF PACKAGING MATERIALS

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Abstract: *Fungi have been used for centuries for a variety of purposes, including as a source of food, medicine, and industrial products. In recent years, there has been growing interest in using fungi strains to obtain novel biomaterials with unique properties that can be used in various applications, including in the field of biotechnology. One example of a fungi strain used for obtaining novel biomaterials is Ganoderma lucidum, also known as the reishi mushroom. This strain has been shown to produce polysaccharides with antioxidant and anti-inflammatory properties, which have potential applications in the development of nutraceuticals and pharmaceuticals. Aspergillus oryzae strain is widely used in the production of a traditional Japanese seasoning called koji. Koji is used to break down starches and proteins in foods, and it has been found to have a variety of potential health benefits, including improving digestion and boosting the immune system. Fungal mycelium of the mushroom species Schizophyllum commune, which has been used to create a biodegradable packaging material that has properties similar to polystyrene foam. This material is sustainable, compostable, and can be produced using waste products, making it an eco-friendly alternative to traditional packaging materials. Overall, the use of fungi strains for obtaining novel biomaterials has great potential for the development of new and sustainable materials with unique properties. As research in this area continues to expand, it is likely that we will see even more exciting applications for these versatile organisms.*

Key words: *fungi strains, biomaterials, novel materials, packaging, composites*

1. INTRODUCTION

Mycelium-based biomaterials are materials that are made from the root structure of mushrooms, which is called mycelium. Mycelium is a natural and renewable resource that can be grown into a range of shapes and structures, making it a versatile biomaterial. Mycocomposites are a type of biomaterial that are made from a combination of mycelium (the root-like structure of fungi) and a natural fibrous substrate such as agricultural waste or wood chips [1]. Mycelium grows by breaking down organic matter, and when it is combined with the substrate in a controlled environment, it forms a strong, lightweight, and durable material that can be used in a variety of applications. To create mycelium-based biomaterials, mycelium is grown in a controlled environment, where it forms a network of tiny threads called hyphae. These hyphae can be mixed with various organic materials such as agricultural waste, sawdust, or straw, to create a composite material that can be molded into a desired shape. The resulting material is then dried and processed to create a durable and biodegradable product. Mycelium-based biomaterials have a number of potential applications, including packaging materials, building materials, and textiles. They are biodegradable, compostable, and have a low environmental impact compared to traditional petroleum-based materials. They are also lightweight, strong, and insulating, making them a promising alternative to traditional materials in a wide range of industries [2].

2. CONTEXT

Mycelium packaging (Fig. 1) is a sustainable and eco-friendly alternative to traditional packaging materials such as plastic or Styrofoam. It is made from mycelium, the root structure of mushrooms, which is a natural and renewable resource that can be grown into a range of shapes and structures. Packaging waste is a growing environmental problem around the world. According to the United Nations Environment Programme, up to 85% of all plastic packaging is discarded and not recycled. This has led to a buildup of plastic waste in landfills and in the environment, with devastating consequences for wildlife and ecosystems. The need for alternative solutions to packaging waste has never been more pressing [3]. Governments and companies are looking for sustainable and eco-friendly alternatives to traditional packaging materials such as plastic, which are causing significant harm to the environment.

Fig. 1: Mycelium derived packaging materials
(Source: www.weforum.org; www.naturamushrooms.com)

Biomaterials, including mycelium packaging, offer a promising solution to this problem. They are made from natural and renewable resources, and are biodegradable and compostable. Unlike traditional petroleum-based materials, biomaterials do not release harmful chemicals into the environment when they break down, and they do not contribute to the buildup of plastic waste in landfills [4]. The use of biomaterials in packaging is gaining traction among companies and consumers alike. Major corporations such as Dell, IKEA, and Ecovative Design are already using mycelium packaging, and others are exploring the use of other various biomaterials.

However, the adoption of biomaterials as a replacement for traditional packaging materials faces some challenges. For example, biomaterials are still relatively new and not yet widely available or cost-effective. They also require specific conditions for production, such as controlled environments and specific materials for growth. Despite these challenges, the potential benefits of biomaterials in reducing packaging waste make them a promising solution for a more sustainable future. As research and development continue, the adoption of biomaterials in packaging is expected to grow, leading to a more environmentally friendly and sustainable packaging industry [5].

3. CURRENT PRODUCTS

Companies such as MycoWorks (Fig. 2) and Ecovative Design (Fig. 3) have developed mycelium-based products such as furniture, packaging, and building materials. MycoWorks is a California-based biotechnology company that specializes in developing sustainable biomaterials using mycelium, the vegetative part of the fungus. Ecovative Design is a New York-based biomaterials company that specializes in developing sustainable alternatives to plastic foam and other petroleum-based materials. The company also produces other mycelium-based products such as MycoBoard, a sustainable alternative to particleboard, and MycoFlex, a flexible material that can be used in footwear and other applications. These types of materials have the potential to make a significant impact on reducing plastic waste and promoting a more sustainable future.

Fig. 2: MycoWorks products obtained from fungal mycelium
(Source: www.mycoworks.com)

Fig. 3: Ecovative Design products: shoebox cooler and mycelium chair
(Source: www.ecovative.com, www.forager.bio)

Other examples include several companies that are all working towards developing sustainable alternatives to traditional materials using mycelium, which has the potential to revolutionize various industries and reduce the environmental impact of our consumption habits:

Bolt Threads - a California-based company that uses mycelium to produce a sustainable alternative to leather called Mylo (Fig. 4); Mogu - an Italian company that produces mycelium-based materials for use in furniture, interior design, and other applications (Fig. 5); Biohm - an UK-based company that uses mycelium to produce sustainable building materials such as insulation, panels, and bricks (Fig. 6); Mycelium Solutions - a Netherlands-based company that produces mycelium-based packaging materials (Fig. 7); Grown.bio - a Spanish company that produces mycelium-based leather alternatives and other sustainable biomaterials (Fig. 8).

Fig. 4: Bolt Threads’ Mylo material and Stan Smith Mylo™ adidas
(Source: www.boltthreads.com)

Fig. 5: Mogu’s acoustic panels made from fungal myceliyum
(Source: www.mogu.bio)

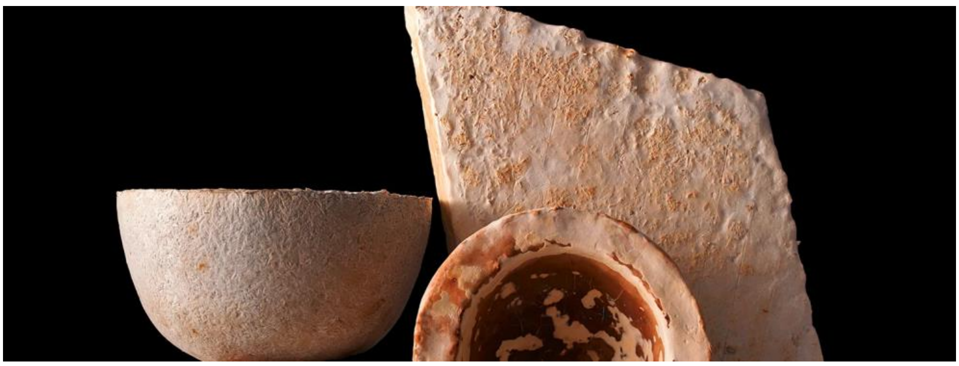

Fig. 6: Mycelium insulation material
(Source: www.biohm.co.uk)

Fig. 7: Mycelium obtained foam materials and composites
(Source: www.myceliummaterials.nl)

Fig. 8: GROWN bio mycelium packaging materials
(Source: www.grown.bio)

The future of packaging materials is increasingly being shaped by concerns over sustainability and reducing carbon dioxide footprint. With the world becoming more aware of the impact of plastics and other traditional packaging materials on the environment, companies are looking for alternative biomaterials that can replace them [6]. One of the main drivers of this shift is the need to reduce the carbon dioxide footprint of packaging. Packaging materials contribute significantly to greenhouse gas emissions, and companies are now looking for ways to reduce this impact [7]. One solution is to use biodegradable materials that can break down naturally, without releasing harmful chemicals into the environment. In conclusion, the future of packaging materials is likely to be shaped by the need to reduce carbon dioxide footprint and increase sustainability. Biomaterials offer a promising alternative to traditional packaging materials, offering a range of benefits including lower carbon footprint, biodegradability, and recyclability. As companies continue to invest in research and development of these materials, we can expect to see a shift towards more sustainable and environmentally friendly packaging solutions in the future [8].

Mycelium composites offer several advantages over traditional packaging materials, including a lower carbon footprint, biodegradability, and compostability. They are also lightweight, strong, and flexible, making them an ideal choice for a wide range of applications. In addition to their sustainability credentials, mycelium composites are also highly versatile. They can be molded into a wide range of shapes and sizes, making them ideal for packaging a wide range of products. They can also be coated with natural materials, such as wax or oil, to improve their water resistance and durability.

In conclusion, mycelium composites are a highly promising source of alternative packaging materials that offer a range of benefits over traditional materials. As research and development continue in this area, we can expect to see an increasing number of companies exploring the use of mycelium composites in their products. With their sustainability credentials, versatility, and low environmental impact, mycelium composites are likely to play an important role in the future of sustainable packaging materials.

4. CONCLUSIONS

Mycocomposites have several advantages over traditional materials such as plastic or wood. They are biodegradable, sustainable, and can be produced using low energy inputs. Additionally, mycocomposites have excellent insulation properties, and they can be molded into various shapes and sizes. They are also fire-resistant and can be engineered to have specific properties such as water resistance, strength, or flexibility. Mycocomposites are being explored as a potential alternative to traditional materials in a range of industries, including packaging, construction, and furniture production. They offer a promising solution to some of the environmental challenges we face today, and they have the potential to be a sustainable and eco-friendly material of the future.

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DIVERSITY OF VEGETABLE-TANNED LEATHER FOR SUSTAINABLE DEVELOPMENT

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Abstract: *sustainability is a major concern to stakeholders in the leatherwork industry. The reason is that other materials are being used in the production of artifacts that were hitherto produced using vegetable-tanned leather. African mask is one artifact that people use as wall hangings for decorations which are usually produced using wood. If it is made from leather, the problem of people associating religious or spiritual activities with it can be reduced, and it can also be a source of income. As a result, it's critical to expand the range of applications for this vegetable-tanned leather in order to maintain both its production and the value chain activities that support the life of those working in the leather sector. Due to this, the study utilized a studio research methodology to investigate additional uses for vegetable-tanned leather in order to diversify the leather industry and ensure the long-term viability of this business. The study demonstrated the adaptability of vegetable-tanned leather and showed how it could be used to create molds from carved wood. When accurately described, the carved wooden object has attractive qualities and can be used for aesthetic purposes in home design. As a result, leatherwork will become more sustainable because it may be used in other contexts as opposed to the traditional artifacts like wallets, bags, sandals, and footrests, which are strongly linked to the usage of vegetable-tanned leather.*
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Key words: *Mask, Studio, raw hides, skins, pelts, Indigenous.*

1. INTRODUCTION

For thousands of years, humans have used animal skin and hides as useful materials [1]. Animal skin was discovered by early man to be a resourceful clothing material necessary to protect himself against the adverse weather conditions, which sparked frantic efforts to develop better methods of conserving it [2].

Local tanners have created Ghanaian native vegetable-tanned leather as the main raw material for usage in a variety of leather products. Any economy could consider leatherwork to be a crucial activity. People may acquire basic necessities like footwear, containers, and furniture as well as a means of subsistence thanks to the leatherwork industry [3].

Leather tanning is one of the first human activities, and early man discovered that various treatments applied to the pelts (raw skins and hides) helped to stop bacterial activity on the by-product of their food supply, which was the decomposition of the pelts [4]. Beyond clothing, leather's physical characteristics have influenced its use in a variety of beneficial ways, including the creation of more cozy, warmer bedding, shelter, seating, and other acceptable uses. These uses extend beyond clothing and include the treatment of animal hide and skin with plant extracts [5].

Leather is well known for having "desirable properties" that make it flexible, strong, and useful in a variety of applications. [6]. Tanning materials derived from plant sources are thought to be less harmful to the environment compared to those derived from chromium. However, they still possess favorable properties such as high tensile and tearing strength, flexibility, ability to stretch without breaking, air permeability, insulation, and resistance to bending fatigue. The process of vegetable tanning involves using tannin-rich tree barks and leaves to treat the hides and skins. The northern part of Ghana is noted for processing leather using this tanning process. The study there used the vegetable tanned leather from the northern part of Ghana. Vegetable-tanned leather can be used for a variety of purposes. Due to its qualities, including workability, splendor, stretch, adaptability as fabric or as hard as wood. Vegetable tanned leather is also strong enough to with stand pressure. Early understanding of leather's potential as a material that could be worked to create a variety of items to meet societal needs influenced the development of advanced technology, which allowed them to increase the diversified uses of leather. One such use is the leather African mask, which is typically made of wood [7]. Observations regarding Ghana's leather industry indicates that for more than a century of leatherwork practice in the nation has not resulted in any notable improvements to the profession relative to what is practiced elsewhere in the world [8].

According to the researchers, taking concrete steps to diversify the uses of locally sourced, vegetable-tanned leather in the creation of novel, contemporary items would enhance the sustainability of the leatherwork industry on both the domestic and global markets. Therefore, the potential of vegetable-tanned leather will be greatly increased if it is successfully used to create African masks, which up to now have not been produced using it as the primary method.

In order to meet current demands for national development, Adu-Agyem and Peligah [9] argued that it was necessary to investigate the materials and technologies already available locally in order to improve them. Expanding the use of locally produced, vegetable-tanned leather from Ghana for the manufacture of African masks will boost employment prospects in the industry and promote sustainability and environmental friendliness [10].

Vegetable tanned leather

Vegetable-tanned leather is a type of leather that is processed without the use of chemicals. Instead, natural substances such as vegetable extracts or tree bark are used. This technique is considered to be eco-friendly and gives the leather a more natural and organic look. Additionally, this method results in strong and long-lasting leather that ages beautifully. Many luxury leather goods such as wallets, purses, belts, and shoes are made using vegetable-tanned leather [11].

Unlike other types of leather that may involve the uses chemicals in the tanning process, vegetable-tanned leather utilizes plant extracts rich in tannins throughout the leather tanning process. The finished product of vegetable-tanned leather showcases the natural fibers of the hide, resulting in a strong and organic appearance. Due to its durability and resistance to microbes, vegetable-tanned leather is frequently used for saddles, holsters, and footwear [12].

The use of vegetable tanning produces leather that has a unique appearance and exceptional durability, owing to the expertise and meticulous application of traditional methods that have evolved over time. With frequent use and exposure to the environment, vegetable-tanned leather is likely to develop a vintage look. This type of leather has a longer lifespan compared to chrome-tanned leather, as it undergoes a gentle process that takes several weeks to complete. Products made from vegetable-tanned leather, such as shoes, become increasingly comfortable over time due to its breathable nature [13]

Once the tanning process is complete, leather that has been subjected to vegetable tanning can either be left in its natural state or colored using various chemicals. Although vegetable-tanned leather can be dyed, it's important to note that the color of this type of leather may change slightly over time. Factors such as exposure to sunlight or water may cause the color to fade or become more intense. However, as vegetable-tanned leather develops a unique and attractive antique look over time, this characteristic is often considered desirable [14]

2. AFRICAN MASK

One of the most common kinds of art in Africa south of the Sahara is the mask. They are connected to almost all of the fundamental components of the local life forces wherever they emerge. In a nutshell, they frequently serve as social control agents, and as a result, they comply with both established practices and required general appearances. In some tribes, masks are used in place of figures to represent ancestors or to restrain their power. Masks exhibit a wide range of shapes, sizes, and overt expressiveness as art forms [15].

Anyone who has had even a brief exposure to this kind in museums or collections can quickly identify it. If it is frequently impossible to understand the significance and purpose of African figure sculpture simply by looking at its external shapes and how they interact, it is even more difficult to grasp these fundamentals in a mask [16].

Wooden masks are crafted by numerous African tribes. Using colored pigments made from charcoal, fruits, and trees, the person will carve the wood into a design before painting it. During rituals or cultural ceremonies, people don the masks. Africans view masks as having a spiritual and religious significance. They assume a new identity when participating in ceremonies while wearing masks. In the mask, they take on the form of the subject or creature [17].

Strict guidelines are followed when creating each African mask, as the craftsmen believe that the materials used, as well as the colors and shapes incorporated, possess a certain power that guides their artistry. These masks hold great significance in African culture, serving as ceremonial attire and conveying symbolic messages about events such as celebrations, wars, death, and emotions. Through music and dance, the masks are brought to life and used to recount the history of a particular tribe. While some masks are intended for public use, others are not. They are fashioned from a variety of materials including bone, ivory, metal, fiber, and primarily wood [18].

The masks may take on natural or abstract forms, often characterized by bold geometric shapes, and are representative of various qualities like nobility, beauty, courage, humor, and more. One thing that is common to all masks is: They are expressions of inner feelings and not copies of nature [19]. The researchers are of the view that in modern civilizations using vegetable-tanned leather will turn this into a decorative leather artifact and therefore will defuse the association of religious worship with it. This there will broaden the usage of vegetable-tanned leather and also aid in the sustainability of leatherwork and conservation of wood or forestry as there is an alternative for mask material.

3. MATERIALS AND METHOD

The study mainly employed the experimental research process and depended much on studio activities. These studio activities required the usage of materials such as vegetable-tanned leather, wooden carved mask, stretching boards, thumb tugs, wooden board's sea-sand, and white glue spatula burnisher. The purposive sampling process was used to select the materials for this research. The research process was carefully observed and meticulously recorded.

3.1. Preliminary preparation for mask formation

The vegetable-tanned leather is given a second treatment to remove excess flesh and eliminate the offensive odor that emanates from it. This was done by sanding the flesh side and also immersing it in a lime solution after which it was stretched on a board to dry.

3.2. Experiment: molding leather on a carved wooden mask

The mold carved from wood was selected from a stock of masks. This was then laid on a board. The vegetable-tanned leather was soaked in a plastic basin for four hours to soften it for the process. Simple leather work tools were employed for the process. This includes thumb tugs, mallets, spatula, brush and burnisher. The leather was spread over the mold and cut to size. It was then positioned on the mould and aligned for pre-picking of the projected relief details. After pre-picking the leather was covered with polythene and left on the mould overnight to set on the mould. With the hand and spatulas, the minor details were carefully picked, and the leather surface was burnished for refined projection of the sunk and lower relief details. As the moisture content reduced appreciably to a bone-dry state, the leather surface was smoothened and the tension was released. The leather was exposed to dry on the mould to permanently assume the shape of the mould. Finally, the leather was removed from the wooden mould to obtain the first leather mask. Finishing of the leather mask was carried out by trimming the rim and a solution prepared from sea sand and wood glue was used to coat the interior circumference of the leather mask to reinforce it. Support was prepared with a straw board and a frame design and constructed and fixed on the support. The work was mounted on the support and the edge was thonged with whip thonging technique.

Fig. 1. Mounted Mask.

Fig. 2. Finished leather mask

Fig. 3. Carved wooden mould

Fig 4. Finished leather mould

4. RESULTS AND DISCUSSIONS

The vegetable-tanned leather is processed and conditioned to achieve moulding processes. The properties of vegetable-tanned leather such as softness, suppleness, and mouldablity were achieved after the soaking process. The soaking process during the experiment restored the suppleness of the leather after the preliminary treatment of the leather. The researchers release that vegetable-tanned leather can be moulded on the wooden mask to achieve the desired shape as the mould. The researcher discovered a single mould can be used to produce several copies of the mask, therefore, reducing the usage of wood and using leather for unconventional products, therefore, promoting the sustainability of leatherwork.

5. CONCLUSION

The experimentation of using vegetable-tanned leather has proven that it can be conditioned and molded into the mask and other carved works with all the aesthetic features of the carved mould being clear and visible. Also, the experimentation has shown that the soaking of vegetable-tanned leather has an impact in it pick out the shapes and features.

The study outcome indicates the versatility of leather as a material for the production of masks and carved wood artifacts which is an unconventional material used in that regard. This, therefore, will improve the sustainability of the usage of vegetable-tanned leather and the leatherwork industry in Ghana.

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ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

SILVER NANOPARTICLES APPLICATION FOR TEXTILE CONSERVATION

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Abstract: *Silver is a metal well known for its antimicrobial properties and it is widely used in a broad range of applications (e.g., dyes, cosmetics, medicine etc.). Therefore, the attempt to use silver for textile cultural heritage conservation does not come as a surprise. However, the real challenge is to achieve a perfect fixation of these particles on textiles without altering the aesthetic aspect of the materials. In this context, the use of silver as nanoparticles is essential to ensure that none of the visual aspects is affected, such as color, texture, brightness etc. For the present work, different types of textile fibers were subjected to an accelerated aging process, using UV light, temperature, and humidity. The fibers selected for this study are natural, artificial and combination. In parallel, the textile fibers were treated with different dispersions containing silver nanoparticles and subjected to the same process. To make a comparison between the levels of degradation of the treated and non-treated fibers, they were characterized using different techniques. Electronic microscopy was used to observe the visual effect of the degradation. Infrared spectroscopy was performed to evaluate the changes in the functional groups of the polymeric structures and colorimetry measurements were carried out to quantify the color change of the fibers.*

Key words: *silver nanoparticles, textiles, heritage, conservation***.**

1. INTRODUCTION

Textiles are indispensable objects for humankind. They reflect the evolution of society and the development of new technologies and materials [1]. Museums around the world include impressive collections of heritage textiles, in various stages of degradation [2,3]. The main method used to preserve them is to maintain a certain microclimate by adjusting the temperature, humidity, and brightness of the rooms where they are exposed or stored [4]. One of the main factors which has a strong impact on textile degradation is the contamination of microorganisms [5]. Silver compounds are well known for their biocidal properties against both bacteria and fungi [6-8]. The potential application of silver nanoparticle as antimicrobial treatment for cultural heritage conservation has been studied on limestones, paper, and cotton fabrics [9-11].

For this work, cotton, polyester, and mixture (50% cotton, 50% polyester) fabrics were subjected to an accelerated aging process, in a special chamber equipped with UV lamps with controlled temperature and humidity. In parallel, the textile fibers were treated with different dispersions containing silver nanoparticles and subjected to the same process. The fabrics were characterized using electronic microscopy and infrared spectroscopy. Also, colorimetry measurements were carried out to quantify the color change of the fibers, to evaluate the influence on the visual aspect of the fibers.

2. EXPERIMENTAL

2.1 Materials and methods

Five samples from each type of fabric, cotton (170 g/m^2), polyester (144 g/m^2), and cotton-polyester mixture (210 g/m^2), all measuring 11×9 cm were exposed to accelerated aging conditions, in a uv chamber (a QUV accelerated weathering tester device) following the working cycle reported in our previously study [12]. The instrument was equipped with fluorescent UV-B lamps (UVB-313), with a wavelength peak at around 313 nm, having nearly all their energy concentrated between 280 nm and 360 nm. All types of samples were collected every three days, having in the end five samples of each type at different degrees of degradation. These samples were characterized and compared to a reference sample (unexposed textile material). In parallel, all three types of fabrics were treated with two types of solutions: glycerol solutions in ethanol (1:1 volume ratio) and Arabic gum (AG) solution (2 g/L in water, prepared on a hot plate at 80°C for 30 minutes). The fabrics were also treated with silver nanoparticles (AgNPs) (180 ppm), purchased from Sigma Aldrich, with the particle size < 100 nm, dispersed in the two previously prepared solutions. The dispersions with AgNPs were agitated in an ultrasound bath at 60°C for 90 minutes. The fabrics were treated via pulverization, then they were left to air dry overnight. The treated fabrics were also exposed to the accelerated aging conditions mentioned above to make a comparison.

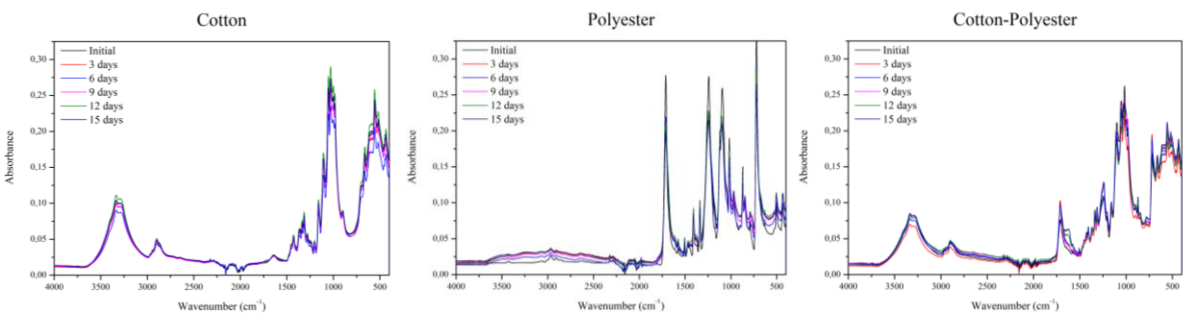
2.2 Characterization techniques

IR spectra were recorded using an FT-IR-ATR instrument from ThermoFisher, over a spectral range of 4000-400 cm-1. The fiber morphology of the samples was evaluated with a FEI Quanta 200 Scanning Electron Microscope (SEM), equipped with an ET detector. The chromatic parameters L*, a*, b* have been measured for each sample, using a Datacolor spectrophotometer Microflash 200d (with a D65/10 lamp).

3. RESULTS AND DISCUSSIONS

3.1 FTIR-ATR characterization

Fig. 1 shows the IR absorption spectra for the textile materials.



a. b. c.

Fig. 1: IR absorption spectra for a. cotton, b. polyester, c. cotton-polyester mixture

The spectra recorded at different exposure times are overlapped to assess the structural changes that might occur during and after the exposure. For all three types of textile fabrics there are no new bands in the IR absorption spectra of the exposed samples compared to the reference fabrics. Only slight changes in the intensity of the bands can be observed. This indicates that the changes at the structural level are minimal, and the fabrics are not significantly altered after exposing them to the mentioned conditions.

3.2 Scanning Electron Microscopy characterization

Tables 1 contain the SEM micrographs of the untreated and treated samples, collected before and after the artificial aging. All images were collected at 4000X magnification.

SEM images for the untreated fabrics do not indicate important changes of the fiber morphology after the exposure procedure, confirming the results obtained from FTIR characterization. The micrographs of the fabrics treated with dispersions 2 and 4 (containing AgNPs) illustrate the distribution of the nanoparticles on the fiber surfaces and show that they were uniformly spread. When analyzing the images of the treated fabrics with the first solution (Gly in EtOH), they seem to present signs of alteration, especially in the case of polyester fabrics, most probably due to the degradation of both textile fibers and glycerol. By applying Arabic gum solution, the integrity of the fibers is maintained after the exposure for cotton and cotton-polyester fabrics. Dispersion 4 (AgNPs in Arabic gum solution) seems to maintain the integrity of the fiber morphology for all three types of fabrics.

Table 1: SEM micrographs of the untreated fabrics before and after exposure to the mentioned conditions.

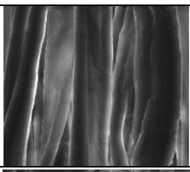
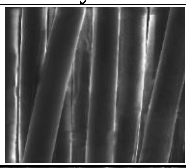
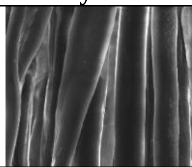
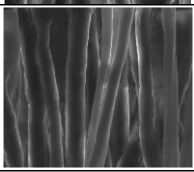
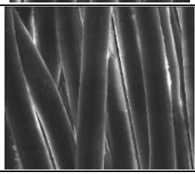
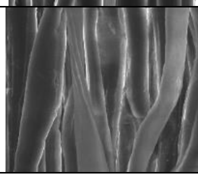
Fabrics	Cotton	Polyester	Cotton-Polyester mixture
Initial fabrics			
Exposed fabrics			

Table 2: SEM micrographs of the treated cotton fabrics before and after exposure to the mentioned conditions

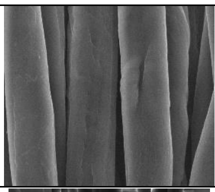
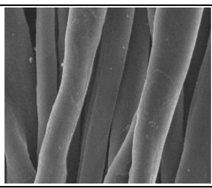
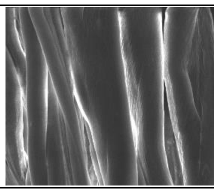
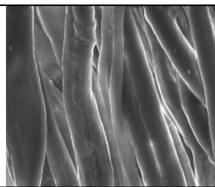
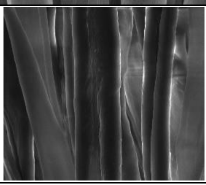
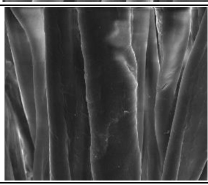
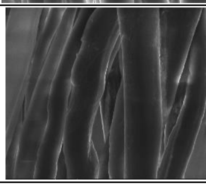
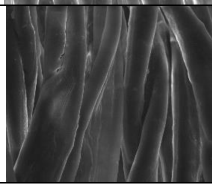
Fabrics	Dispersions (1=Gly sol., 2=AgNPs in Gly sol., 3=AG sol., 4=AgNPs in AG sol.)			
	1	**2**	**3**	**4**
Initial Cotton fabrics				
Exposed Cotton fabrics				

Table 3: SEM micrographs of the treated polyester fabrics before and after exposure to the mentioned conditions

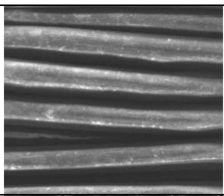
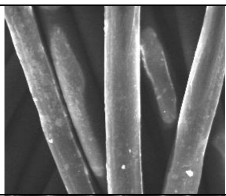
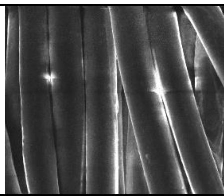
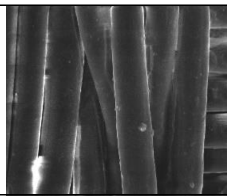
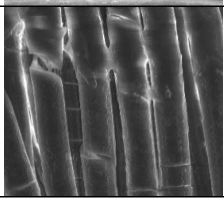
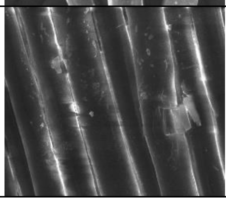
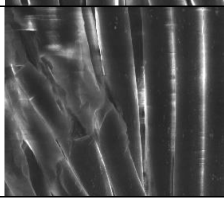
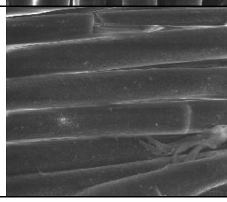
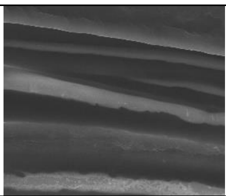
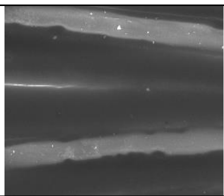
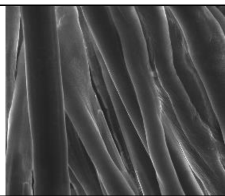
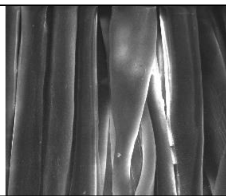
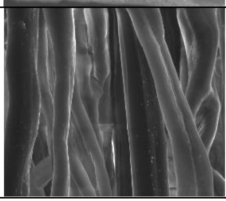
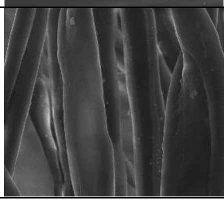
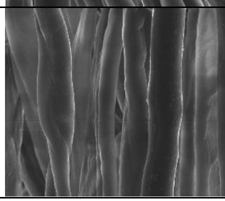
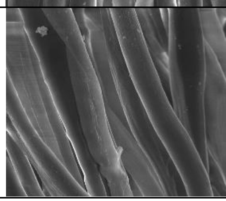
Fabrics	Dispersions (1=Gly sol., 2=AgNPs in Gly sol., 3=AG sol., 4=AgNPs in AG sol.)			
	1	2	3	4
Initial Polyester fabrics				
Exposed Polyester fabrics				

Table 4: SEM micrographs of the treated otton-polyester mixture fabrics before and after exposure to the mentioned conditions

Fabrics	Dispersions (1=Gly sol., 2=AgNPs in gly sol., 3=Arabic gum sol., 4=AgNPs in Arabic gum sol.)			
	1	2	3	4
Initial Cotton-Polyester mixture fabrics				
Exposed Cotton-Polyester mixture fabrics				

3.3 Colorimetric analysis

The chromatic parameters measured for each sample are listed in Table 5. The brightness of the samples is represented by the parameter L*, on a scale from 0 (for black) to 100 (for white). If a* and b* are positive, the color of the sample will be in the red-orange-yellow range. If a* is negative and b* is positive, the color of the sample will be in the yellow-greenish-green range. If a* and b* are negative, the color of the sample will be in the green-turquoise-blue range. If a* positive and b* negative, the color of the sample will be in the range of blue-purple-red. ΔE* represents the total color difference between the sample and the reference and is calculated according to the formula: $\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$ [13].

The color of the untreated fabrics does not change significantly after exposure. The most affected seems to be the cotton-polyester mixture, for which the parameter b* increases from 1,42 to 11,13, indicating a color shift to yellow. Pure cotton presents increased resistance against degradation. When comparing the treated and unexposed fabrics, the dispersion which affects mostly the visual aspect of the textiles is the glycerol solution. Therefore, the glycerol-based dispersion is not suitable to be used for conserving textile cultural heritage. Also, it is observed that by adding AgNPs in the solution the color changes increase. The fabrics treated with Arabic gum solutions present the lowest values of ΔE, showing that these ones suffered the least changes of color. Furthermore, the change in color of these fabrics is minimal even after exposing them to the mentioned conditions. When studying the fabrics treated with the AgNPs dispersion in Arabic gum solution, it is observed that the changes in color after exposure are minimal compared to the case of the untreated fabrics and in the case of cotton-polyester mixture fabric the value of ΔE is even lower (from 9,93 to 8,17). The unexposed samples treated with dispersions 3 and 4 did not show visible changes in color. Even if ΔE exceeded the value of 1, in the case of dispersion 4, this change is not visible with the naked eye.

Table 5: Color change between the reference and the treated fabrics before and after exposure

Fabrics	**Before exposure**				**After exposure**			
	L*	**a***	**b***	**ΔE***	**L***	**a***	**b***	**ΔE***
Untreated cotton	92,06	-0,02	2,60	-	91,6	0,05	2,58	**2,02**
Cotton$_1$	83,01	0,88	3,61	**9,15**	92,18	0,11	2,37	**8,94**
Cotton$_2$	78,24	0,71	3,64	**13,88**	89,29	0,18	4,38	**11,02**
Cotton$_3$	92,09	0,07	2,34	**0,27**	92,62	0,12	1,88	**0,78**
Cotton$_4$	89,52	0,10	1,85	**2,64**	88,83	0,18	4,72	**3,01**
Untreated polyester	92,74	-0,12	1,27	-	88,88	-1,43	5,94	**6,1**
Polyester$_1$	88,52	-0,05	1,18	**4,22**	86,13	-0,02	11	**10,02**
Polyester$_2$	83,53	0,17	0,11	**9,29**	85,11	-0,76	8,33	**7,76**
Polyester$_3$	92,54	-0,09	1,35	**0,22**	88,89	-1,42	6,31	**2,70**
Polyester$_4$	90,25	-0,02	1,08	**2,50**	86,90	-1,10	8,41	**8,06**
Untreated cotton-polyester mixture	92,82	-0,15	1,42	-	90,2	-0,96	11,13	**9,93**
Cotton-Polyester$_1$	84,16	0,52	1,54	**8,69**	91,07	-1,15	8,01	**9,81**
Cotton-Polyester$_2$	76,75	0,40	2,31	**16,11**	86,13	-0,18	10,30	**11,70**
Cotton-Polyester$_3$	92,54	-0,15	1,56	**0,32**	91,70	-1,22	6,66	**5,30**
Cotton-Polyester$_4$	89,80	-0,02	1,39	**3,03**	86,70	-0,31	8,97	**8,17**

4. CONCLUSIONS

The three types of textile fabrics used for this study showed an increased resistance against degradation when subjected to an accelerated aging process involving UV light, temperature, and humidity. The IR spectra indicated that the changes at structural level are minimal. This information was confirmed by SEM micrographs and color change parameters. When applying the solution of glycerol, the fibers present signs of degradation after the exposure procedure. By adding AgNPs to the solutions and treating the fabrics with the resulting dispersions by pulverization, it can be observed that the nanoparticles are well dispersed over the surface of the fibers. The Arabic gum solution with dispersed AgNPs that was pulverized on the fabrics seems to have the best effect of maintaining the integrity of the fibers for all three types of fabrics. The visual aspect of the fabrics was the least modified when using the Arabic gum solution. Also, the presence of the AgNPs did not seem to have a significant effect on the color changes after the exposure. Given their tremendous antibacterial and antifungal effect and combined with the fact that they do not have an important impact over the visual aspect of the textile fabrics, silver nanoparticles represent a promising treatment for cultural heritage conservation.

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ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

FASHION INDUSTRY CHARTER FOR CLIMATE ACTION AND GLOBAL FASHION INDUSTRY

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Abstract: *Fashion Industry Charter for Climate Action is consequence of a long-term international meeting chain, called the COP-Conference of Parties. The COP is an international climate conference that unites the signatory countries (195 countries + the European Union) of the United Nations Framework Convention on Climate Change (UNFCCC) since 1995. The goal of the consecutive meeting chain is to manage the interiorization of the Convention and negotiate new commitments.*
Fashion Industry Charter for Climate Action is prepared and launched by the patronage of UN Climate Change at COP24 in Katowice, Poland, in December 2018 and renewed at COP26 in Glasgow, UK, in November 2021. The stakeholder of the charter is the global fashion stakeholders including textile, apparel and clothing industries with a holistic commitment. The charter contains the vision to achieve net zero emissions by 2050 in line with keeping global warming below 1.5°C from pre-industrial levels defined in the COP 21 of Paris Agreement in 2015.
In line with the launched charter, planned tasks of global fashion industry are focused on decarbonisation, reduction of greenhouse gas emission (GHG), renewable electricity utilisation across supply chains, implementation of tools and measures about broadening climate actions. Therefore, the paper is aimed to inform and increase the awareness about current climate actions of global fashion industry.

Key words: *Climate change, fashion, textile, apparel, COP, green house gases (GHG)*

1. INTRODUCTION

Climate change, global warming, excessive rain, unexpected meteorologic events become major issues over the world. Increase on greenhouse gas emission (GHG) is one major reason for the climate disruption, that was started right after the industrial revolution era and augmented drastically by the raising number of consumer society. The growth in the frequency and violence of natural disasters, melting icebergs, and climate refugees are expected results of the irresponsible behaviour shown by past and current industrialized generations. It has been reported that global fashion industry caused about 2.1 billion tonnes of GHG in 2018, equalling 4% of the total global emission. Raw material manufacturing and the rest of the related manufacturing phases are responsible for about 70% of the fashion industry's emissions, where the remained 30% is associated with retailing, consumer use-phase and end-of-life sessions. Beside the current influence on the total GHG emission, it has been estimated that GHG emission of the fashion industry will become around 2.7 billion tonnes a year by 2030 with an annual increase ratio of 2.7% [1]. Therefore, fashion sector has acted, with the other industrial sectors, to protect the environment and organize action plans and about pollution problems. Aware of the damage caused to the environment and its consequent harmful effects; international organisations, goverments, climate professionals, academics [2], [3], [4], [5], [6], [7] and citizens, have decided to commit themselves to minimizing the impact of their activities concerning the future of the planet. To act, for the last few decades, several numbers of political meetings have been organized to discuss the climate issues and sign agreements and charters setting out actions to be taken in order to limit the resulting impact as soon as possible.

In this study, historical background of the Fashion Industry Charter is introduced starting with the earliest COP meeting chains, COP 21 Paris Agreement and Fashion Industry Charter for Climate Action of COP 24 and COP 26. Fashion Industry Charter for Climate Action is introduced with its consequences; reciprocity and reflection of the action terms in the global fashion industry are searched; and in line with the launched charter, planned prevention tasks of global fashion industry is listed.

2. CONFERENCE OF PARTIES - COP

Concerns about the world climate have officially started with the initiation of World Meteorological Organization (WMO) and UN Environment Programme (UNEP) the Intergovernmental Panel on Climate Change (IPCC) in November 1988. After the early establishment of IPCC, scientific assessment reports about management the risk of excessive natural occarences and disasters are analysed at international level. First official report of IPCC was released in November 1990, during the 2nd World Climate Conference Call for Global Treaty with the statement of *'emissions resulting from human activities are substantially increasing the atmospheric concentrations of greenhouse gases'*. One month later, on December 10, 1990, the UN General Assembly established the Intergovernmental Negotiating Committee (INC) for a Framework Convention on Climate Change where more than 150 states discussed binding commitments, targets and timetables for emissions reductions, financial mechanisms, technology transfer, and 'common but differentiated' responsibilities of developed and developing countries. An official text about Climate Change is prepared and adopted the United Nations Framework Convention in May 1992; and it is opened for signature at the Earth Summit in Rio on June 1992, bringing the world together to curb greenhouse gas emissions and adapt to climate change.

The United Nations Framework Convention on Climate Change (UNFCCC) entered into force on March 21, 1994, and countries that sign the treaty are known as 'Parties'. Participating 196 Parties meet annually at the Conference of the Parties (COP) to negotiate multilateral responses to climate change. First Conference of the Parties (COP 1) was organized in Berlin in April 1995, where Parties agreed that commitments in the Convention were 'inadequate' for meeting Convention objectives. The Berlin Mandate established a process to negotiate strengthened commitments for developed countries, thus laying the groundwork for the Kyoto Protocol. COP 21, on December 12, 2015, held in Paris with 195 nations, known as Historical Paris Agreement, was accomplished with the aggreement to combat climate change and unleash actions and investment towards a low-carbon, resilient and sustainable future [8].

The Paris Agreement marked a turning point in the fight against global warming, as it commits all the countries of the world to '*reducing their greenhouse gas emissions and keeping warming below the 2°C mark by 2100'* and efforts continue to *limit the warming below the 1.5°C*, according to Article 2.1. of the Paris Agreement [9].

After the Paris Agreement of COP21, succeeding venue and virtual COP meetings are conducted on different locations through a roughly defined road map to fight global warming. The

Fashion Industry Charter [10] was launched at COP24 in Katowice, Poland, in December 2018 and renewed at COP26 in Glasgow, UK, in November 2021. On COP 27 the decisions taken in Sharm El-Sheikh require all countries to make an extra effort to address the climate crisis [11].

3.FASHION INDUSTRY CHARTER FOR CLIMATE ACTION

Launched and improved fashion industry charter of 2018 and 2021 define the specific tasks, which are grounded on Paris agreement, under eight working groups of “Decarbonization pathway and GHG emission reductions”, “Raw material”, “Manufacturing/Energy”, “Logistics”, “Policy engagement”, “Leveraging existing tools and initiatives”, “Promoting broader climate action”, “Brand/Retailer Owned or Operated Emissions”.

Consequence of the charter, companies are expected to reorganise their business models. Officially stated expectations are focused on:

-Support the goals of the Paris Agreement in limiting global temperature rise,
-Reduction of GHG around 30% by 2030 against a baseline of no earlier than 2015,
-Analyze and set a decarbonization pathway for the fashion industry,
-Quantify, track and publicly reporting the GHG emissions,
-Partner with experts to develop and implement a decarbonization strategy,
-Selection of materials with low-climate impact (priority),
-Energy efficiency measures and renewable energy in the value chain,
-Not to install new coal-fired boiler or power generation,
-Preference to low-carbon logistics,
-Action improvement towards circular business models,
-Close dialogue with consumers to increase awareness about the GHG emissions,
-Partnership with finance community to built up a low-carbon economy,
-Develop a strategy advocating the development of policies and laws about climate action,
-Establish a dialogue with governments in key countries to enable systemic change,

4. REFLECTION OF THE CHARTER ON FASHION SECTOR, CONSUMERS AND MANUFACTURERS

Implementation of the charter on global textile, apparel and fashion sector resulted with some positive improvements alongside the stake holders. Raw material manufacturers, yarn, fabric manufacturer companies, textile chemical additive brands, apparel designers, home laundry equipment manufacturers, home washing brands, wastewater treatment initiations, textile recycling companies, academics, governmental and non-govermental organisation started to take interest on the commitments of the charter. Manufacturer, retailer, and designer companies all over the world are become partner or member of local or global organisations to train, learn, improve and implement charter requirements on their business model [12], [13].

Consumers are expected to learn more about environmental effects of fashion, and change their fashion approaches, shopping habits, and washing practices supporting the commitments of the charter. Consumer behaviours are expected to change according to the below listed practices [14].

-Preferring organic or recycled fabric: Utilisation of organic cotton, recycled cotton, or polyester helps reduction on impact level up to 99%. Regenerated cellulosic fiber utilisation is also reported as preferred fiber.

-Repairing the clothes: As result of fast fashion, shopping habits are changed to the direction of buying, charter rules the consumer to make repairing instead of buying new textile items.

-Second hand shopping habits: Second hand shops or second-hand internet pages promote recycling, reuse, and upcycling in textile.

-Change fiber preference to the organic flax and hemp: Clean fabric, clean fiber terms should become part of regular shopping habits where less water, less chemical consumption is practised.

-Buying from the local manufacturers: Clothing and textile shopping selection should be made considering the environmental, logistical, and social costs of the manufactured country.

-Prefer to buy transparent brands: Brand selection should be made considering the transparency policy of the brands, where reliable sustainability reports are published

-Wash the textile and apparel items properly: Home laundering should be made at moderate temperatures of 30 to 40°C, that is enough heat to remove the dirt. Plan the washing cycle of clothes properly. Prefer to use less harmful washing agents, detergents, or soap.

Textile manufacturers are also expected to implement new habits and practices during their production phases in the content of raw material selection, energy, and waste management. Textile manufacturers behaviours are expected to change according to the below listed practices:

Raw material

-Utilization of man-made fiber group that has reduced environmental impacts

-Utilization of plant-based fibres that require less amount of water, synthetic fertilizer, pesticides, and herbicides compared to those of cotton growing.

-Extension of natural coloured cotton agriculture practices over current cotton growers in the world.

Energy

-Implementation of renewable energy sources such as solar, hydropower, landfill gas (LFG), or geothermal energy.

-Generation of the electricity, hot water, and steam needs of textile factories with combined energy systems (cogeneration), where electricity and heat are produced simultaneously.

-Use of energy-efficient engines and drive systems in the machinery and equipment.

-Ensuring to operate heating, ventilation, humidification, and air conditioning systems in optimum conditions.

-Adaptation of automated systems to increase efficiency in energy management.

-Reduction of unnecessary electric consumption to benefit from natural lighting in sustainable textile manufacturing facilities.

-Achievement of predictive maintenance plans in textile manufacturing operations.

Waste management

-Widespread use of heat recovery applications from wastewater pipes and exhaust gas in textile dyehouses.

-Reuse of rinse water and less polluted water with a mixture of fresh water in textile wet processing.

-Use of less harmful, bio-based, and biodegradable sizing agents alternatives.

-Reuse of wastewater including textile wet process additives such as sizing agents, mercerization agents, and dye pigments.

-Upcycling of fabric waste generated in ready-made garment manufacturing stages.

-Collection and mechanical/chemical recycling of post-consumer textile wastes.

5. CONSLUSION

Textile items are one common consumable product all over the world. Annual textile fiber production has reached 110 million tonnes which is about 13 kg of annual fiber consumption per person in the world. Rising textile consumption brings additional undesired issues beside the desired prosperity to humanbeing. Each kg of fiber consumption causes varying types and varying amount of environmental harm of GHG emission and global warming. It is reported that share of fashion, textile, and apparel industries has reached to the 4 % of total GHG emission in the world.

To control the GHG emission of the industries there are preventing measures and actions of personal, local, governmental, and international levels. Disincentive steps are raised both from top to bottom or vice versa. Internatianol actions to increase awareness and set regulations continue during the last 45 years with the meeting chain of COP.

Beside international meetings, organisations, and rules; governmental, local and individual awareness is also increasing to manage the GHG emission of fashion industries. Decarbonised material production, improved material mix, decarbonized material mix, minimized production wastage, decarbonized garment manufacturing, minimized manufacturing waste, increased utilisation of sustainable transport, minimized packaging, decarbonized retail operation, minimized returns, minimized stock wastage, increased use of rental model, increased rate of recommerce model, introduction of refurbished – upcycled product, repair service implementation, reduced, washing-ironing-drying, and increased recycling collections are a series of precaution to control the share of fashion industry's GHG.

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ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

ANTIBACTERIAL TREATMENT OF KNITTED FABRICS MADE OF FIBER BLENDS USING TUMBLER-TYPE EQUIPMENT

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Abstract: *Microbes can be carried by and even multiply on textiles, which can act as reservoirs containing infectious agents such as bacteria, viruses, and fungi and could be vectors of infection in hospitals or communities. Scientific studies demonstrated two scenarios concerning the interrelationships between microorganisms and textiles: textiles can transmit microorganisms and thus infections, and textiles containing antimicrobial agents prevent the transmission of infections. This study aimed to evaluate the behavior in finishing specific knitted textile structures of different fiber compositions, designed, and produced for obtaining antibacterial knitted garments for people with special needs, using a conventional finishing agent and application method to be ready for application on tumbler-type industrial equipment. Different assortments of fibers, yarn compositions, and knitted fabric geometry were used to produce knitted textile materials. For acquiring an antibacterial effect, a bacteriostatic product based on silver chloride and titanium dioxide was used for the finishing of knitted fabrics, which was applied by exhaustion method, on a tumbler-type laboratory apparatus. Antibacterial activity was assessed by agar diffusion plate test on E. Coli and S. Aureus test strains. Higher inhibition zone values are obtained in the case of knits made of conventional fibrous blends (cotton/acrylic fibers), compared to the variants containing Bamboo, Lenpur, and Coolmax fibers.*

Keywords: *antibacterial textiles, knitted fabrics, finishing, functional knitted garments, tumbler-type equipment*

1. INTRODUCTION

Many infections spread through clothing and textiles. In certain conditions of temperature, humidity, and lighting, some microorganisms develop and proliferate on the surface of porous materials, including textiles. Microbes can be carried by and even multiply on textiles, which can act as reservoirs containing infectious agents such as bacteria, viruses, and fungi and could be vectors of infection in hospitals or communities [1]. Bacteria and other microorganisms adhere to all types of surfaces by a sequence of four processes: transport (diffusive, convective, active movement), initial adhesion, attachment, and colonization of surfaces. If the surfaces can be designed to minimize or alleviate the adhesion of microbes, then the materials will be more effective in many situations and environments [2]. Scientific studies demonstrated two scenarios concerning the interrelationships between microorganisms and textiles: textiles can transmit microorganisms and thus infections, and textiles containing antimicrobial agents prevent the transmission of infections [1]. The incorporation of antimicrobial agents on textile products, able to stop the spread of microbes, is of utmost importance, thus antimicrobial fabrics have become an important issue in the textile industry. Antimicrobial textiles can be termed based on their specificity against microbes, i.e., antibacterial, antifungal, or/and antiviral. Depending upon the treatment and antimicrobial compound used, e.g organic and inorganic antimicrobial agents, plant and fruit extracts, animal-derived compounds, dyes, and mordants [3], [4], [5], the antimicrobial fabric may be leaching type or non-leaching type, while based on its mechanism it can be biocide (kill the microorganisms) or biostatic (inhibits their growth). For clothing, biostatic fabric is preferred as they preserve the natural bacterial flora of the skin and have no adverse effect on human skin, while the biocidal fabric is preferred for medical and environmental applications [6]. This study is part of a research project aimed at obtaining functional knitted textile products by finishing on tumbler-type industrial apparatus.

2. MATERIALS AND METHODS

2.1 Textile materials

Knitted textile materials used in this study were designed and produced by SC DATSA TEXTIL SRL within Competitiveness Operational Program 2014-2020, by using different assortments of fibers, yarn compositions, and knitted fabric geometry, as detailed in Table 1. Yarns containing Bamboo, Lenpur, and Coolmax fibers were added in some knitted variants to improve the comfort and the antibacterial effect of the final products.

Table 1: Knitted fabrics subjected to antimicrobial treatment

Sample code	Fiber composition of yarns	Fabric geometry	Mass (g/m^2)
1A	50/50% cotton/acryl, Nm 30/2; 100% Bamboo, Nm 34/1	Ajour	292.8
1As	50/50% cotton/acryl, Nm 30/2	Ajour	203.8
3A	50/50% cotton/acryl, Nm 30/2; 100% Lenpur, Nm 34/1	Plain Jersey	334.5
3As	50/50% cotton/acryl, Nm 30/2	Plain Jersey	227
1O	50/50% cotton/acryl, Nm 30/2; 100% Lenpur, Nm 34/1	Rib	521.7
1Os	50/50% bbc/acryl, Nm 30/2	Rib	358.6
1C	50/50% bbc/acryl, Nm 30/2; 100% Coolmax, Nm 50/1	Honeycomb	337.5
2C	50/50% bbc/acryl, Nm 30/2; 100% Bambus, Nm 34/1	Honeycomb	407.3
1Cs	50/50% bbc/acryl, Nm 30/2	Honeycomb	402.1

2.2 Antibacterial agent

For acquiring an antibacterial effect on knitted fabrics, Sanitized® T 27-22 Silver (Sanitized AG, Switzerland) based on silver chloride and titanium dioxide was used as an antibacterial agent due to its safe bacteriostatic effect against many gram-positive and gram-negative bacteria, including MRSA, yeasts, and micro-fungi. According to the producer it effectively reduces the formation of bacteria and odor, acting on the bacterial cell membrane, which inhibits cell function and blocks the respiration and vital food intake of bacteria.

2.3 Finishing procedures

Antibacterial finishing was applied by exhaustion method, on tumbler-type laboratory apparatus “Redkrome” (Ugolini-Italy) equipped with an 8L container. Hydro-extraction and drying were made on a tumbler drying machine. The sequence of technological operations and operation parameters was as follows: scouring with 1 g/L nonionic wetting agent and detergent, based on fatty alcohol polyglycol ether (Kemapon PC/LF, Kem Color S.p.a, Italy), temperature 40°C, duration 20 minutes, followed by subsequent warm and cold rinsings, hydro-extraction at 800-1000 rpm, antibacterial finishing with 0.8% Sanitized T 27-22 Silver, liquor ratio 1:10, temperature 60°C, pH=6, duration 45 minutes, hydro-extraction at 800-1000 rpm, and drying at low-temperature range.

2.4 Antibacterial activity assessment

The antibacterial activity of the treated samples was qualitatively assessed by the Agar diffusion method according to the SR EN ISO 20645:2005 standard method -Determination of antibacterial activity-agar diffusion plate test, by using bacterial cultures in liquid medium replicated at 24 hours of ATCC 6538 *S. aureus* (Gram-positive) and ATCC 11229 *E. coli* (Gram-negative) strains test. The textile specimens (18 ± 2 mm in diameter) were placed on the surface of the nutrient medium and then incubated at 37 ± 1°C for 24 h. Inhibition zones were calculated using the following formula:

$$H = (D - d) / 2 \tag{1}$$

where: H is the inhibition zone [mm]; D – is the total diameter of the specimen and inhibition zone [mm]; d – is the diameter of specimen [mm].

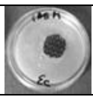
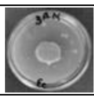
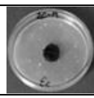
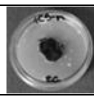
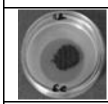
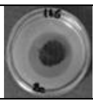
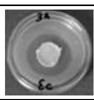
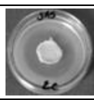
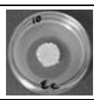
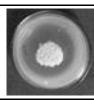
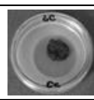
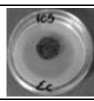
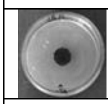
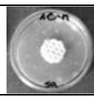
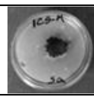
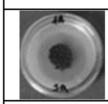
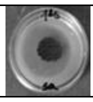
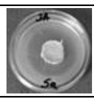
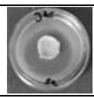
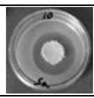
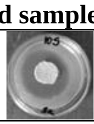
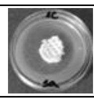
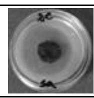
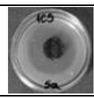
For bacterial growth, the contact zone under the samples was determined with a microscope at 20× magnification. Following the standard method, the inhibition zone was measured in mm and the degree of bacterial growth was estimated in the nutrient medium under the specimen.

3. RESULTS AND DISCUSSION

Antibacterial activity

Images of Petri plates after 24 h incubation and the inhibition zone (mm) of the knitted fabric variants subjected to antimicrobial treatment are shown in Table 2.

Table 2. Images of Petri plates and inhibition zone (mm) showing antibacterial effect after 24 h against **a.** E. coli; **b.** S. aureus

Sample code	1A	1As	3A	3As	1O	1Os	1C	2C	1Cs
E. Coli test strain/ inhibition zone (mm)	**Reference samples-untreated**								
									
	-	-	-	-	-	-	-	-	-
	Antibacterial treated samples								
									
	9 mm	10 mm	8.5 mm	10 mm	8.5 mm	7.5 mm	8 mm	13.5 mm	12.5 mm
S. Aureus test strain/ inhibition zone (mm)	**Reference samples-untreated**								
									
	-	-	-	-	-	-	-	-	-
	Antibacterial treated samples								
									
	11 mm	12 mm	9.5 mm	11 mm	10 mm	9.5 mm	12.5mm	15 mm	14 mm

Analyzing the data obtained after antimicrobial testing, the following can be concluded:
- the untreated knitted fabric considered reference does not have an antibacterial effect, the test strains had a significant development, the inhibition zone around the textile samples being absent.
- all knitted fabric variants treated with Sanitized® T 27-22 Silver have antibacterial activity with important inhibition zones between 7,5 mm and 13,5 mm in the case of the *E. Coli* test strain and between 9,5 mm and 15 mm in the case of *the S. Aureus* test strain.
- slightly higher values of the inhibition zone are observed, with a minimum of 1 mm and a maximum of 4.5 mm, in the case of textile materials made of conventional fibrous blends (cotton/acrylic fibers code 1As, 3As, 1Cs), compared to the variants containing fibers with special properties, respectively Bamboo (code 1A), Lenpur (code 3A) and Coolmax fibers (code 1C).

4. CONCLUSIONS

The antibacterial finishing treatment applied by exhaustion method on a tumbler type equipment gives a certain antibacterial effect on knits made of fibrous blends of 50/50% cotton/acrylic fibers with or without blends with other yarns containing fibers with special properties (Bamboo, Lenpur, Coolmax). However, by comparing the two types of knitted supports (with or without fibers with special properties) slightly higher values of the inhibition zone are observed in the case of knitted fabrics made of conventional fibrous blends only.

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ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

IMPACT OF MODIFIED FEED MECHANISM ON SEAM QUALITY OF GARMENTS

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Abstract: *A few distinct feed mechanisms can be found in sewing machines. The mechanism that feeds the material into the machine differs in each machine. In lock stitch sewing machines, the mechanism known as the drop feed is the one that is utilized the majority of the time. Its construction includes one presser foot, one throat plate, and one feed dog. Different types of feed dogs can be used in the drop feed mechanism to achieve the desired level of customization. In this study, modification-1, modification-2, and modification-3 were created in an industrial lock stitch machine using feed dogs with 18, 21, and 30 teeth, respectively. These numbers correspond to the number of teeth on the feed dogs. The quality of the seams, such as the seams on garments, was analyzed after each modification of the feed mechanism performed on seams made of the same fabric (Denim fabric). We took measurements of the seam's strength and efficiency as well as its puckering and slippage. It was discovered that the seam quality of garments constructed using modification-1 (one) is superior to that of garments constructed using the other two modifications using the same fabric. Therefore, to finish a specific garment accurately, it is necessary to select the appropriate sewing machine and ensure that it has the ideal feed mechanism.*

Keywords: *Feed mechanism, Feed dog, Seam quality, Garment*

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1. INTRODUCTION

The sewing machine's feed mechanism controls the movement of the sewn material, making it the most critical component. Each cycle of needle motion must involve a different part of the material being sewn, which means that the material being sewn must move. This motion is referred to as the feed mechanism [1]. Fabrics are fed into the stitch formation zone by feed mechanisms, which then take the stitched fabrics out of the stitch formation zone. Frictional forces between the feed dog and the bottom fabric and several layers of fabric on the same machine, are what propel fabrics ahead. The presser foot's pressure, which is a littlesmallonsiderable quantity, also produces a force that opposes the movement of the cloth. As a result of this opposing force, the top cloth lengthens somewhat, and there may be some displacement between the top and bottom textiles. This indicates that two separate lengths of cloth are striving to match up along the seam, giving the seam the impression of being puckered [2].

It is vital to consider both the dynamic properties of the pressure-feed system and the properties of the fabric to effectively function of the feed mechanism of a periodical action [3]. The performance of a garment's seams is determined by the fabric's structural and mechanical characteristics. The appearance and performance of seams are determined by the types of stitches and seams used, their parameters, seam defects, and seam damages [4]. Presser-foot force may be adjusted to lessen issues, including uneven stitches, distortions, and material deterioration. Because it is a fixed-force system, constant-force control does not provide for the best force setting at all speeds. Closed-loop control enables more exact force adaptation to each stitching specificity's needs. Some sewing characteristics, including those more directly connected to the material feedings process, such as the force applied to the presser foot and the vertical displacement of the presser foot, were occasionally measured by researchers using instrumented sewing machines. The theory that contacts losses between the presser foot and the feed dogs increase with sewing speed and decrease when the presser foot pre-tension is increased was supported by the development of a mathematical model for the movement of the presser foot in a sewing machine as well as experiments [5].

During textile materials' stitching, parameters should be set for optimal reinforcing results in the manufactured composite. The damages of the sewing thread and the reinforcing textile should be minimized. For optimal results, measurement devices were developed to watch the relevant parameters (presser foot distance, needle thread tension) during the stitching process [6]. Additionally, a "maglev" presser-foot controller and an electromagnetic actuator were combined to create the "auto damp" presser-foot active actuation system [7]. This system maintained a consistent force between the presser-foot and the fabric. The effectiveness of the feeding system was assessed by detecting vertical presser-foot displacement using a contactless setup using a Hall-effect sensor [8]. Additionally, to comprehend the root causes of sewing issues, the link between presser-foot force, displacement, sewing speed, and material qualities was examined [9].

In the making of garments, it is seen that all kinds of fabrics are added with the same sewing machine. Every sewing machine has a specific feed mechanism different from other sewing machines. Despite the exact feed mechanism of the same sewing machine used for light, medium, and heavy fabrics, noticeable differences are observed between the feed dog teeth. Feed dogs can have thin or thick teeth where the number of teeth is higher if the teeth are thin and the number of teeth is less if the teeth are thick. Therefore, it has been examined if the number of feed dog teeth on the same machine's drop feed mechanism has to be raised or decreased. Here, it has also been studied to see if the number of teeth on the feed dog makes any difference in the quality of the seams on the clothing.

2. EXPERIMENTAL

2.1 Materials and Methods

The denim fabric (Figure1) with EPI-137, PPI-73, Areal Density-8.36 Oz/yd^2, Warp yarn count-20 Ne and Weft yarn count-4.08 Denier composed of Polyester & Spandex was used to produce superimposed seam.

Fig 1. Denim fabric

The sewing thread was 100% spun polyester containing count of 50/2 Nm. This thread was used to make superimposed seams by an industrial single-needle lock stitch machine (Figure 2). Then universal strength tester (Titan of James Heal Co.) was used to measure the seam strength and seam slippage. Other equipment (measuring scale, balance, GSM cutter) was also used as supporting equipment. In this study, the stitch was performed, keeping all other sewing parameters constant. The following standards (Table1) were followed for the measurement of fabric areal density, fabric strength (warp & weft direction), seam strength (warp & weft direction), seam slippage, and seam puckering for three modified feed mechanisms (Table2) separately.

Fig 2. Lock stitch sewing machine

Table 1. Testing standards and measuring purposes

Testing Standard	Measuring Properties
ASTM D 3776:2013	Areal Density
ASTM D1683-11a (Strip Test)	Fabric Strength
ASTM D1683-11a (Strip Test)	Seam Strength
ISO 13936- 1 & 2	Seam Slippage
AATCC standard 88B	Seam Pucker

Table 2. Modifications in the drop feed mechanism using feed dogs of various teeth

Modification No.	Modified Feed Mechanism
Modification-1	Throat Plate - Presser Foot - Feed Dog (18 Teeth)
Modification-2	Throat Plate - Presser Foot - Feed Dog (21 Teeth)
Modification-3	Throat Plate - Presser Foot - Feed Dog (30 Teeth)

The feed dogs included in the three modifications are illustrated belowFigure3). Here, denim fabric was used, and superimposed seams were produced. It is also mentionable that other machine and process parameters remained constant. After that, all the produced seams for three modified feed mechanisms were tested to identify the seam properties. Finally, it was tried to see the relationship between the modification in feed dog and the seam quality of garments.

18 Teeth 21 Teeth 30 Teeth

Fig 3. Different feed dogs for three modifications in feed mechanisms

3. RESULTS AND DISCUSSION

3.1. Seam strength analysis

The seam strength in the warp and weft direction is indicated in Table 3.

Table 3. Seam strength (Warp wise and Weft wise)

Modification in Feed Mechanism	Seam Strength (N) in Warp direction	Seam Strength (N) in Weft direction
Modification-1	156.56	178.54
Modification-2	154.47	166.87
Modification-3	153.07	165.14

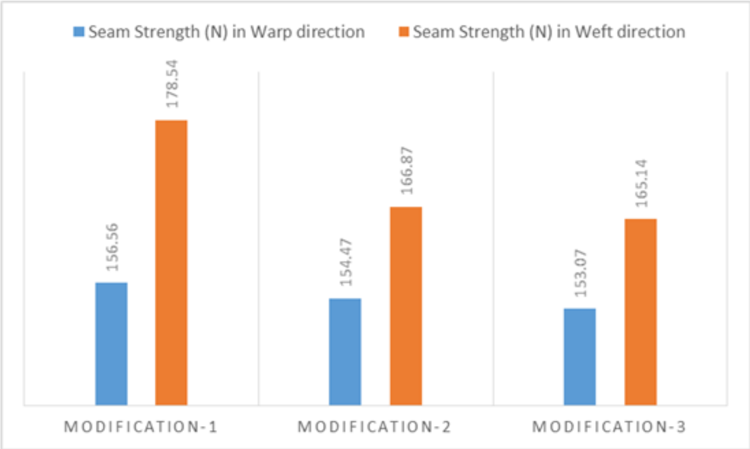

Fig 4. Seam Strength (Warp and Weft wise)

In figure 4, it is clearly shown that the seam strength is the highest for both warp and weft direction in case the case of modification-1, i.e., lower no. of teeth of feed dog gives the better result than higher no. of teeth as the higher no. of teeth of feed dog may damage the fabric during sewing for having more fabric contact.

3.2 Seam Efficiency Analysis

The seam efficiency in the warp and weft direction is indicated in Table 4.

Table 4. Seam Efficiency (Warp wise and Weft wise)

Modification in Feed Mechanism	Seam Efficiency (%) in warp direction	Seam Efficiency (%) in weft direction
Modification-1	20.15	22.39
Modification-2	19.88	21.21
Modification-3	19.74	20.08

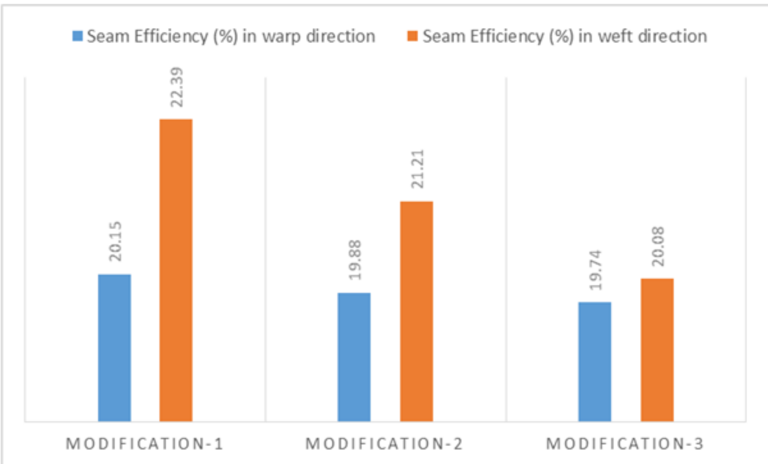

Fig 5. Seam Efficiency (Warp and Weft wise)

Figure 5, shows that the seam efficiency is the highest for both warp and weft direction in the case of modification-1 i.e. lower no. of teeth of feed dog gives a better result than a higher no. of teeth as the higher no. of teeth of feed dog may damage the fabric during sewing for having more fabric contact.

3.3 Seam Slippage Analysis

The seam slippage in both warp and weft directions is given in Table 5.

Table 5. Seam Slippage (Warp way and Weft way)

Modification in Feed Mechanism	Seam Slippage (mm) in warp direction	Seam Slippage (mm) in weft direction
Modification-1	3	5.3
Modification-2	5	6
Modification-3	5	6.33

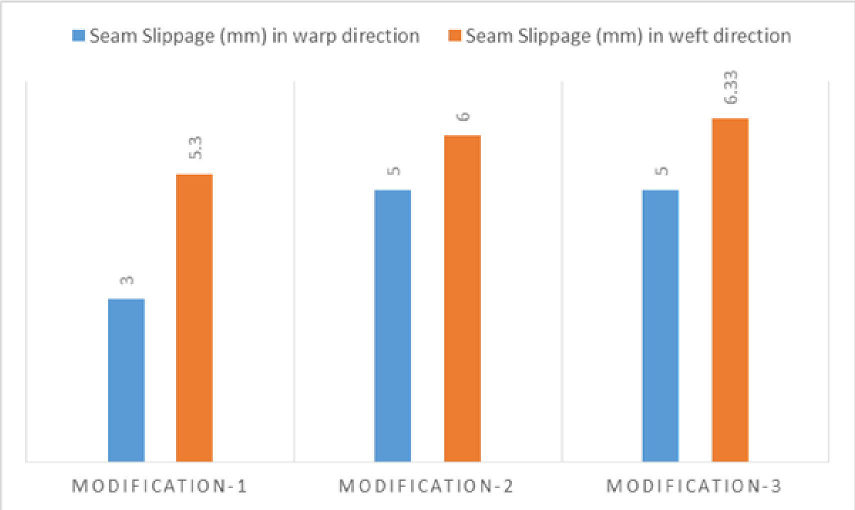

Fig 6. Seam Slippage (Warp wise and Weft wise)

In figure 6, it is clear that the seam slippage is the lowest (good) for both warp and weft direction in the case of modification-1, whereas seam slippage is the highest in the case of modification-2 due to the improper feeding of fabric by the feed dog of higher teeth during sewing.

3.4 Seam pucker analysis

The seam pucker in both warp and weft directions is given in Table 6.

Table 6. Seam Pucker (Warp wise and Weft wise)

Modification in Feed Mechanism	Seam Pucker in warp direction	Seam Pucker in weft direction
Modification-1	4	4
Modification-2	4	4
Modification-3	4	4

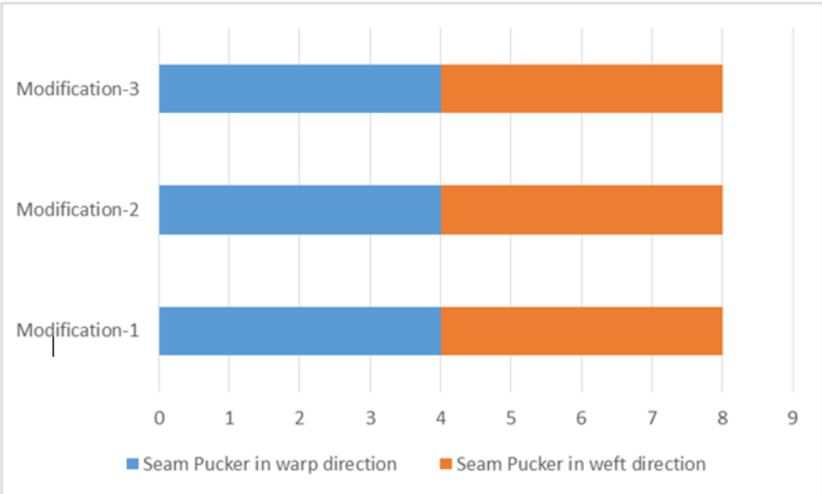

Fig 7. Seam Pucker (Warp wise and Weft wise)

Figure 7 represents that the seam pucker is the same for both warp and weft direction in case of all modifications (1, 2 & 3).

4. CONCLUSIONS

The results of this study make it easy to confirm that the same machine (lock stitch sewing machine) and the exact feed mechanism (drop feed mechanism) cannot be used for sewing all kinds of fabrics (light, medium, and heavy) and will also change the quality of the garment seam. So, choosing the proper sewing machine with the perfect feed mechanism is necessary to complete a specific garment correctly.

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ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

SIMULATING THE FITTING OF A PATTERN USING THE ASSYST ® 3D VIDYA PROGRAM

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Abstract: *This paper aims to present the evolution of pattern construction in the textile industry starting from the manual construction of the basic pattern and ending with the current 3D method that is offered by most computer-aided design softwares. In this paper, the authors have chosen to present the way to simulate the fitting of a ladies' tunic and therefore to focus on the 3D Vidya design module, which is included in the computer-aided pattern making program Assyst. The computer-aided design program Assyst is in the top 3 of the kind programs used on the European market, the latest development being the 3D Vidya design module. Vidya's 3D module is now even more powerful, with incredibly realistic shadows and results thanks to the new V-RAY rendering system and PathTracer technology. With Vidya, one can instantly create avatars of the target group or a model in any size - all with lifelike sizes, shapes and realistic measurement increase or decrease across the full size range, which can be implemented in the shortest possible time. All digital accessories for simulation such as zippers, buttons, snaps have the characteristics of real accessories and behave as such, so in a simulation you can visualize exactly how a zipper behaves while in use.*

Key words: *Assyst Vidya, simulation, apparel pattern making, 3D design.*

1. INTRODUCTION

The basic pattern is made according the normal conformation of the body, so any modification can be made for that product with more ease. The pattern is built based on measurements taken directly on the body, according to individual orders, but it is recommended that these measurements be proportional (calculated), as this is necessary to form a clearer picture of the body's conformation [1]. Manual making of apparel patterns has been replaced in the apparel industry almost entirely by modern and efficient computer-aided design systems. Work patterns and templates can be digitally emailed across the globe so they can be immediately accessed and used [2]. In the industrial practice of pattern making, existing basic patterns are predominantly used and modified for achieving new patterns. By means of a CAD system the work is significantly easier and the execution time is reduced.

Thus, either manually drawn patterns are used that are digitized, or the basic patterns already existing in the database. The entire outline of the pattern can be modified, deleted or added, lines and points can be changed, whole pieces can be moved [3].

2. GENERAL INFORMATION

The ease of working with and the multitude of tools, commands and functions that serve drawing, modeling and styling, have made graphic programs increasingly used and beloved in the textile industry [4], [5], [6].

With Vidya, work orders or complete digital samples or swatches can be launched very quickly, they are always based on the desired material and real colors and on the body dimensions of the target group. In this paper, the authors have chosen to present the way of simulating the fitting of the women's tunic [7], [8].

2.1. Model fitting simulation in Vidya

So that the pattern can be opened for simulation in Vidya, the following steps must be taken: we select the right avatar, in the case of the female avatar, then we select background colors, and finally we can remove the default clothing object, as it appears in **Fig. 1**.

Fig. 1: Selecting the right avatar according to the desired imported model

The avatar is basically the body, which the fitting of the clothing item is simulated on. Workspace parameters form surrounding settings like background color, light setup, removing the default clothing item. The start of the simulation is presented in, **Fig. 2**.

Fig. 2: Start of the simularion

2.2. Initial positioning of the pattern pieces

To position the pattern pieces, the following steps are required: activate the "hull" surface mode. .

The pattern pieces are to be placed one by one, by clicking the left mouse button and with "drag & drop", adjusting the position of the pieces can be done later, after positioning thesee for the back also, return to the rotation mode by activating the button  from the main upper menu, **Fig. 3**.

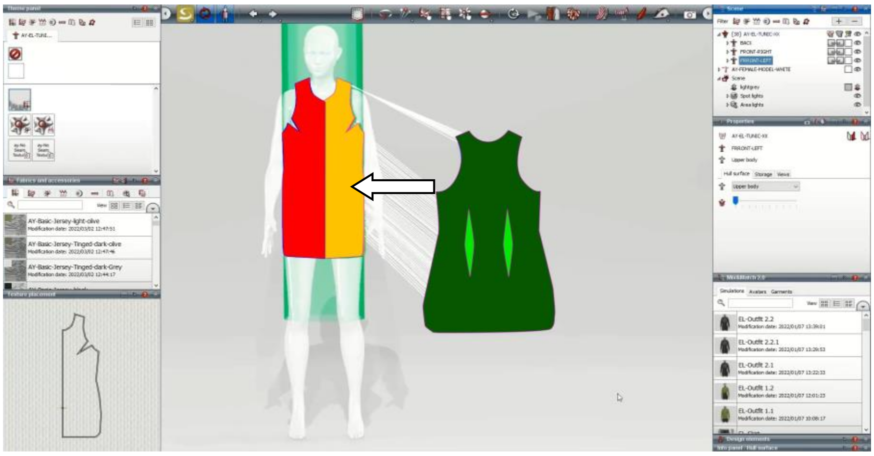

Fig. 3: Placing the pattern pieces

The appearance of the avatar after positioning the landmarks and selecting the sewing simulation function, is presented in **Fig. 4**.

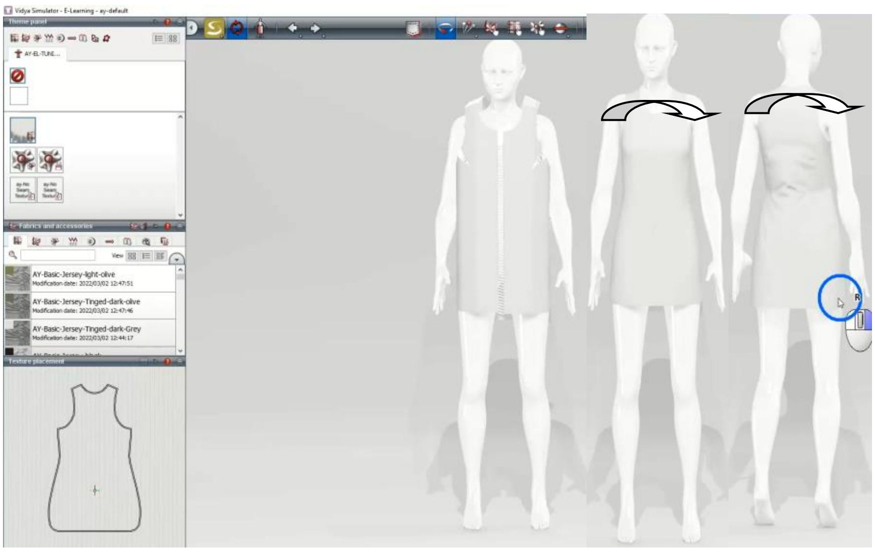

Fig. 4: Avatar appearance after the sewing simulation

Thus, many established companies have opted for the 3D Vidya module, among them are worth to be mentioned: Gerry Weber, Gore, Marc O'Polo, Hessnatur, Vaude, Giesswein, Strauss, Escada, Esprit and many others [7], [8].

3. CONCLUSIONS

The efficiency of the 3D Vidya module can be seen and tracked closely within the design and CAD department of a company, based on the collection sketches, the technical documentation and design of the product can be directly drawn. The Vidya module by choosing the material or materials in the case of a combination and specifying the composition that includes the rendering by the program of its specific behaviors, allows to carry out an accurate fitting simulation. The chosen avatar corresponds to the desired measurements, so the changes that are considered necessary after the fitting are as real as possible. In the clothing industry characterized lately by globalization where the production partners are far away, it is a major advantage to reduce the time and costs invested in making the initial sample.

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ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

CONCEPT OF AUTONOMOUS TEXTILE FOIL KITE - WIND ENERGY GENERATOR

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Abstract: *This paper presents the starting phase of a research project that aims to develop the technological demonstrator of a wind power generator system using a wind sail to capture the high altitude wind energy. The sail will capture the wind energy and will be raised to an altitude of minimum 100-200 meters to capture the stronger and more constant winds at this altitude.*
Flight attitude control will be done via an active control hub named WCU (Wing Control Unit) attached to the cable at about 10m from the sail.
The ground station will be made up, at large, of a drum that will hold and wrap the push-pull towing and control cable, a flywheel for storing the mechanical energy, a centrifugal clutch coupled to an electric motor used in rewinding the towing cable on the drum and of course the electric generator.
The system will have an electronic command and control unit within the WCU. This control system will automatically launch the sail from the platform, guide the sail to the cruise altitude, control of the flight trajectory in the wind and on the return path, optimal landing on the platform in case of storm or other weather vagaries.
The demonstrator system will be sized to generate approximately 20kVA. Current calculations show the need of a sail area of about 25m^2 to achieve this power ratting.

Key words: *Foil Kite, Wind Energy, Electric Generator, Autonomous Flight, Technical Textiles*

1. INTRODUCTION

Among new technologies of producing electricity from renewable resources, a new type of wind energy generators have been in develpment. These systems are called Airborne Wind Energy Systems (AWE) and employ flying tethered kites to reach winds found at atmosphere layers that are inaccessible to traditional wind turbines. Research on airborne wind energy systems started in the mid-seventies.

The high level and the persistence of the winds that blow above 100m from the ground surface have attracted the attention of several research communities.

Among the different AWES concepts, there are Ground-Gen systems in which the conversion of mechanical energy into electrical energy takes place on the ground and Fly-Gen systems in which such conversion is done at the aircraft level such as depicted in fig.1.

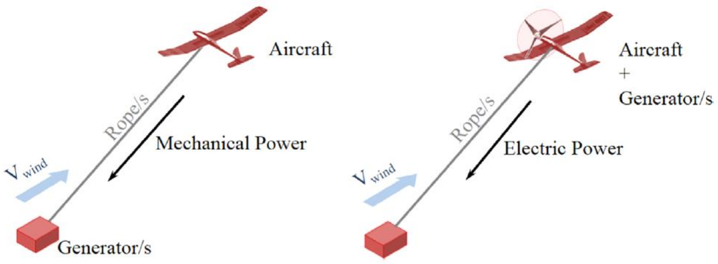

Fig.1: Examples of Ground-Gen and Fly-Gen.

Fly-Gen systems and Ground-Gen systems with fixed wing airborne unit (AU) are among the most successful technologies nowadays, however these suffer from a really bad scalability factor and higher costs as the weight and complexity of the airborne units is getting higher exponentially when targeting a higher power output.

This project however is not about fixed wing airborne units, what we trying to develop is an GroundGen AWESs that uses a foil kite as AU that can launch and land autonomously with the help of an WCU (Wing Control Unit) attached to the cable bellow the kite sail.

2. GENERAL INFORMATION

The GWA from IRENA website https://irena.masdar.ac.ae/gallery/#map/103 contains digital global maps of average wind speed and wind power density on 3 height levels (50, 100 and 200m) in raster format with a spatial resolution of about 1x1km. They cover all inland areas (onshore), as well as 30 km offshore. On https://globalwindatlas.info website, users can visualize wind speed and power density maps, as well as explanatory layers (including orography, roughness length and roughness index), and can download synthesis wind data for countries and regions within countries.

Based on these maps [1] we can observe and compare the wind power potential of Romania 100 to 200m, above this altitude we do not have exact measurements, mainly the eastern part of the country has marginal wind power density at 100m but at 200m its getting fairly good. The higher you get off the ground, the stronger the wind speeds and the more power can be obtained, thus we can harvest more power in a country that has marginal wind power density at the max wind turbine height of avg. 80m.

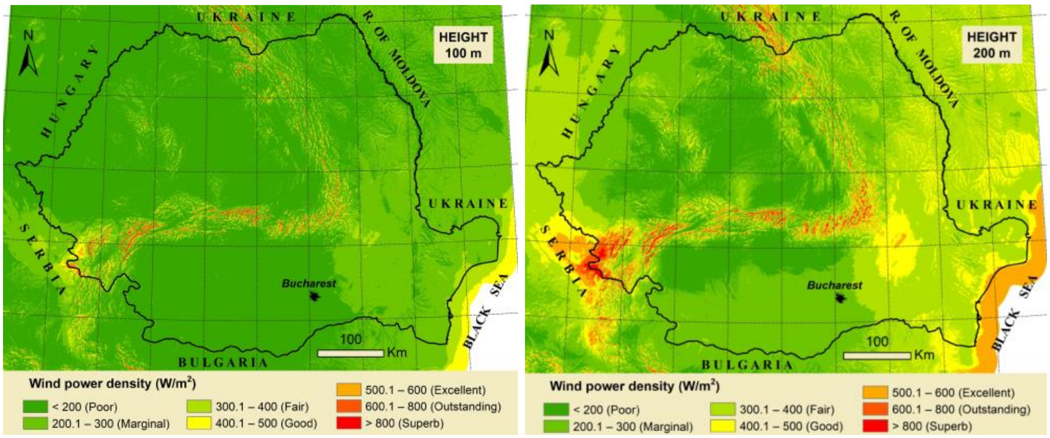

Fig.2: Wind power potential of Romania: 100 to 200m

The wind speed increases with height from the ground level up to the upper troposphere. There are several reasons that explain this. First, the pressure gradient increases with height. Second, and the main reason at the altitudes we operate in this project, the wind speed increase with height, is due to surface friction. Surface objects such as trees, rocks, houses, etc. slow the air as it collides to them. The influence of this friction is less with height above ground, thus the wind speed increases with height. A third reason is due to air density. The density of the air is higher at ground level and decreases with height. At higher altitudes, wind is also more constant, but building tall towers is not feasible, being much too expensive and massive in size. This is where AWE systems come into play.

The main principle of a kite power system is that the kite flight must be controlled to generate high drag in energy generation phase and low drag in recovery phase. By controlling the the kite trajectory, power is generated utilizing a drum that is capable of reeling the cable in-and-out. Power is generated when the cable is relled out and power is consumed when it is reeled back in. The kite is controlled in such a way that the cable tension must be lower during the reel-in phase than the reel-out phase. The larger the difference in power between these two phases, the greater the power will be generated. In order to maintain a proper cable tension, the kite must operate at a high angle of attack. The kite must have an aerodynamic drag sufficient to overcome the cable drag and the weight of the system including cable connected to the drum. Once the cable is pulled at its end it must be reeled back in. To have a positive energy generation, the cable tension must be reduced by lowering the angle of attack of the kite during reel-in phase [2].

The kite maneuveres in two ways: closed orbit and open orbit. In closed orbit both traction and recovery take place in the orbit's period where in the opened orbit the kite altitude increases during traction phase reaching its maximum and then it is reeled down during the recovery phase. For energy generation the kite is put in a closed orbit maneuvering that follows a lying-eight trajectory that minimises the risks of cable tangling and maximises the power generation time span [3].

This flight pattern differs from the ascending/descending circular motion (helical) as illustrated in before which is an opened orbit maneuvering system. However, researches are still being carried out to determine the types of trajectories that result in the optimal net average power produced per cycle [4].

During the first phase of the project we aim in establicshing the system components and dimensioning the experimental model of the system that can help us to better understand and optimise the final product. We started this with the kite and ground generator assemblies.

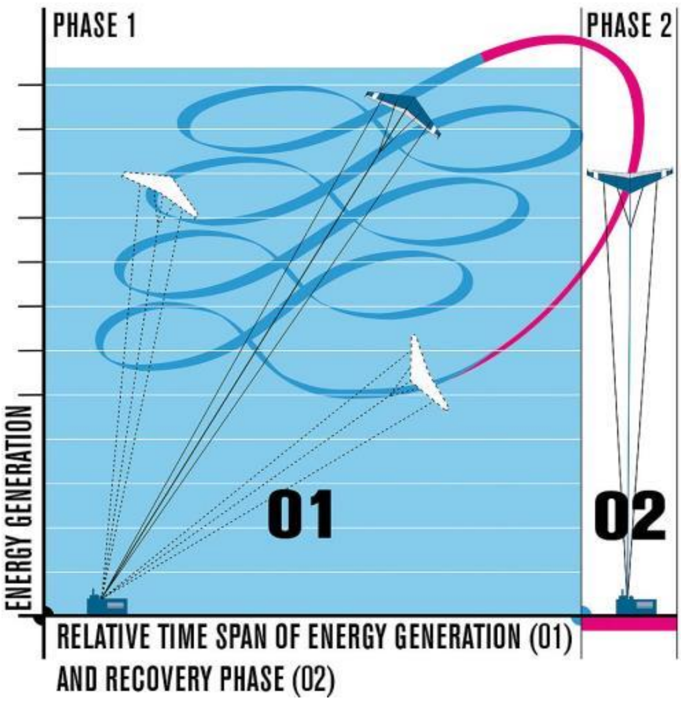

Fig.3: AWEs kite flight trajectory

3. SYSTEM COMPONENTS

Kites can be broken down into two categories based on their design (fig.4):
Leading Edge Inflatable Kites: SLE Kite (a); The C Kite (b); Hybrid Kites; Bow Kites;
Foil Kites: Classic Foil Kite (c); Valve Foil Kite

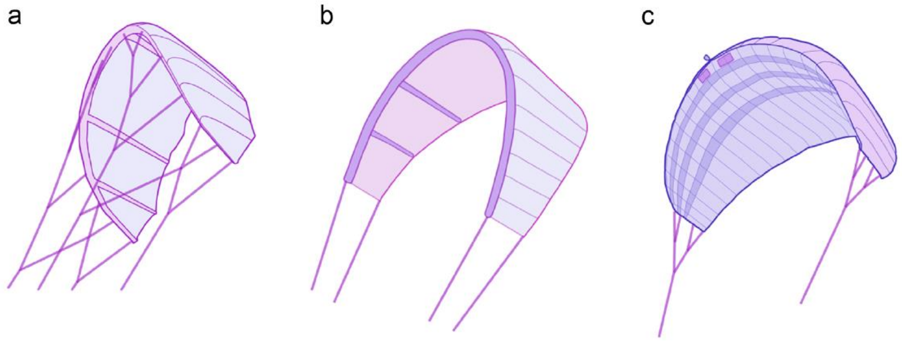

Fig.4: Types of kites

One drawback is that in the long term, the wind will fail, at least 5 percent of the time even in the best locations [5]. When the wind fails the kites must be taken down and put back up when wind is suitable for launch. This usually requires a human operator to properly launch the kites further increasing the time when the system does not generate power. The object of this proposal is to tackle this problem. One aspects of the problem can be solved by automating the take-off and landing of the kites.

Therefore we propose a system that uses as airborne unit a single sail foil kite construction with on-board capabilities to take off and land autonomously. We will use a single kite pulling force to generate power where the cable is reeled out from a drum and the rotation of the drum drives a generator. This process is known as the traction or power phase. After the cable is reeled out for several meters, the kite is configured to low drag force and winched back to its initial position. This process is known as retraction or depower phase. To control the kite’s flight a Kite Control Unit (KCU) is used which incorporates two powerful servos for steering and depowering of the kite.
The KCU is a small, remote-controlled copter suspended a few meters below the kite and is integral part of the launch/landing system. The KCU is basically a copter that will have propeller guards to will prevent accidental collision of the propellers with the kite risers or the kite tether. These guards will greatly reduce propellers efficiency but this is a non-issue as the KCU in active mode will be powered just briefly when needed.

Fig.5 explains the launch/landing sequence, were the kite (c) in collapsed/flaked position hangs bellow the KCU (a), a drogue chute (d) is used to position the kite canopy into wind and maintain the wind facing direction. The slider (b) is used to smooth line deployment and prevent line entanglements. A drum inside the KCU starts to un-reel the kite lines (stage I) causing the kite to catch more wind and consequently inflate until the actual drag cause by the kite equals the KCU lift (stage IIa). At this moment the KCU initiates a roll motion until the system positions upside down (stage IIb). From this time forward the KCU start to depower completely in order to permit the kite to fully inflate and slider to get in the lowest positon just above KCU (stage III).

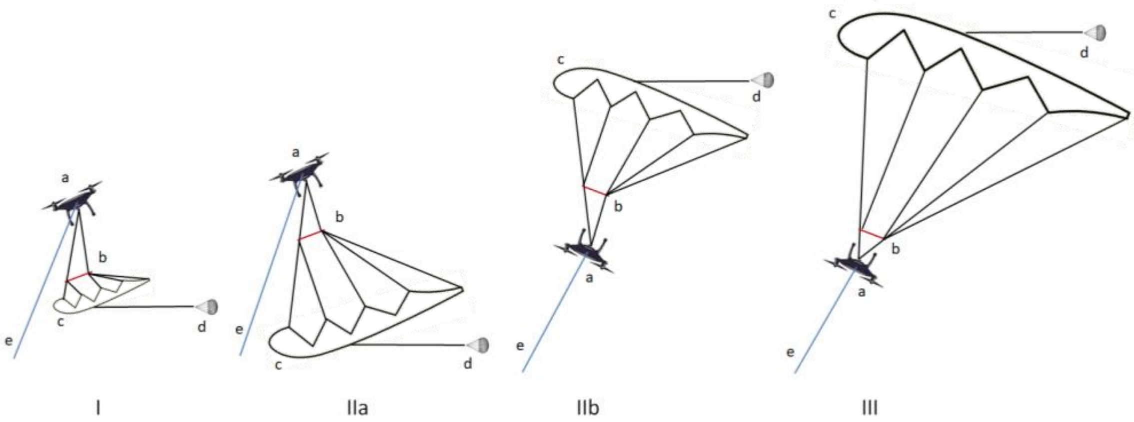

Fig.5: Kite launch/landing sequence

The landing phase will be done in reverse, starting with the lines reeling by the KCU; this will cause a decrease in kite surface area till it reaches the size were the reverse rolling action can be achieved followed by further reeling of the lines inside KCU until the kite is fully flaked bellow and thus the airborne unit can park in a specially designed area next to the ground station.

The ground station of this system consists of a drum, a variable speed electric drive that operates as a generator during the power phase and as motor during de-power phase, a battery module to balance the electrical energy over these alternating or pumping cycles and power electronics.

A simulation model is developed to investigate the power transmission system of the kite power unit, which reflects the torque, speed and power behavior of the modeled ground station transmission line. An overview of the system simulation model is as shown in fig.6.

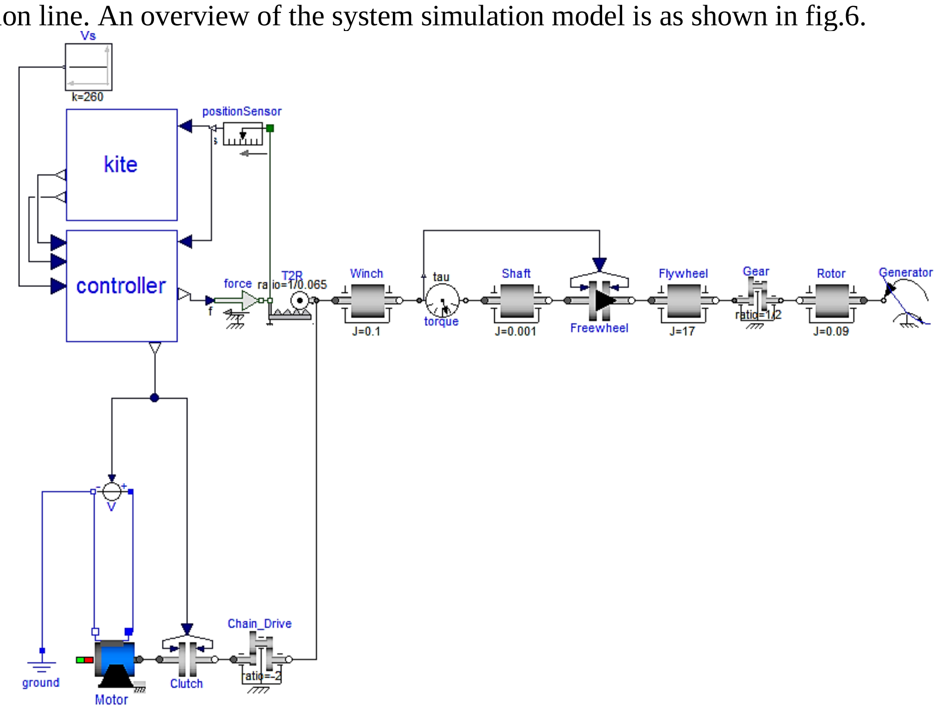

Fig.6: Illustration of the proposed AWEs simulation model

5. CONCLUSIONS

During the starting phase of the project a digital model was developed for kite (1), ground station (1) and control module (1). This model will be further applied further in the process of digital and experimental design of the functional model.

The numerical model reflects the behavior of the torque, speed and power of the transmission designed for the ground station as expected. The kite power unit was designed for a nominal power of 20.5 kW, and from the simulation results a maximum power of 18.5 kW is obtained. A simple control strategy for the kite's open-loop maneuvering system is adopted here to demonstrate the high-altitude wind generation capability. Several factors were not considered while analyzing the simulated results, such as optimal kite trajectories for efficient power generation, friction losses of the cable on the winch, exact kite dynamics, wind speed variations, etc.

It should be noted that the model in question refers to a medium-sized kite of 25 m^2 that generates a maximum theoretical power of 20.5 kW. A conventional wind turbine of the same nominal power weighs about 6 tons and costs about 70,000 euros [6]. The expected weight and cost for the designed system is of around 500-750kg and costs less then that.

To achieve good performance and efficient power production, however, a robust system control adaptable to changing wind conditions must be implemented. To achieve fully automated operation, the kite's flight path, elevation angle, and power delivery modes must be automatically adjusted in real time based on optimal set points. The use of high-efficiency airfoils can lead to further improvements in performance.

It is proposed to continue the project with the development of the digital and experimental design phase of the functional model, which will also include the prototype of the WCU active control system for the automatic control of the launch and landing sequence of the kite.

ACKNOWLEDGEMENTS

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ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

APPLICATIONS OF BATTERIES USED IN THE TEXTILE FIELD

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Abstract: *Batteries are important in our daily lives and are used in various devices, from mobile phones and laptops to electric cars and solar energy storage systems. However, there are other areas where batteries can be used to improve the functionality and performance of products, such as the textile industry. Batteries are critical components in power systems for electronic devices. An emerging application of batteries is in the textile field, where they are used to power electronic devices integrated into fabrics. Smart textile technology has become an important research area, with applications in health, sports and fashion. This technology can be used to monitor the vital parameters of the body, to help improve sports performance and to create clothes with special features, such as heating or cooling. However, for these fabrics to work, a the energy source to power the incorporated electronic devices. This is a critical problem because conventional batteries are bulky and rigid, making integrating them into fabrics challenging. Flexible batteries are a potential solution to this problem. They are made using flexible materials such as polymers or metals. Flexible batteries can be integrated directly into fabrics, making using them in smart textile applications possible.*

Key words: *batteries, smart textiles, functionality, performance, mobility*

1. INTRODUCTION

The development of flexible electronics such as textile heating systems and the desire of users to wear them anywhere has led to intense research on integrating batteries into clothing, miniaturization, performance and ensuring optimal energy consumption to keep the body warm.
Another application of batteries in the textile field is incorporating electronic devices into fabrics. Fabrics that can store and release electrical energy can be used to charge portable electronic devices such as mobile phones, tablets or electronic systems integrated into bracelets for monitoring.

As all electronic devices require energy, developing flexible, lightweight batteries is a significant design challenge for smart textiles [1].

Power generation can be achieved by piezoelectric elements that harvest energy from movement or photovoltaic elements. Human interfaces to active systems can be roughly grouped into input devices and annunciation or display devices. Input devices can include capacitive portions that function like buttons or shape-sensitive fabrics that can sense movement, bending, pressure, and stretching or compression. Advertising and display devices may include material speakers, electroluminescent wires, or wires that are processed to contain arrays of organic light-emitting diodes (OLEDs) [1].

2. BATTERIES USED IN THE TEXTILE FIELD

Batteries can be integrated into wearable e-textile applications, but it is necessary for the electronic device to be energy efficient to limit the battery's size. An efficient, light and flexible source is needed to power all the components in a smart textile.

Ideally, such a source will be a fiber that can be naturally integrated into smart textiles during weaving [2].

Flexible, fiber-shaped batteries embedded in textiles are convenient for charging gadgets like fitness bands, smart watches, and phones. Researchers have made fiber-shaped batteries by twisting or winding different battery materials or coating them in layers on polymer fibers or metal wires. The realization of fiber batteries with high functionality is well reduced to the quality of the material coatings [3].

Recent years have shown rapid progress in research into surface-applied or garment-embedded flexible electronics for various applications, including healthcare and other sensing functionalities, with many of these devices based on conventional electronic circuit elements and substrates, such as printed circuit boards and, therefore, rigid and inflexible, which limits their practical applications on a large scale and also ease of carrying.

These new types of smart textiles provide a means of embedding electronic functions and conductive threads into the fabric to make them smart wearables for various applications. However, like other electronic devices, they need a power source, one of the biggest challenges limiting their commercialization. Integrating the power source into textiles has its own consequences for the wearer's overall well-being, replaceability and flexibility.

Usually, in conventional approaches, rigid and bulky batteries or capacitors are used as energy storage devices for e-textiles. Studies suggest that all battery components must be made of flexible substrate materials to replace these rigid devices or batteries with flexible ones. In addition to flexibility, lightness and comfort, when these textile electronic devices are used explicitly close to the human body, the materials used to build the electronic components, such as the battery, should be non-toxic and environmentally friendly [4].

Power generation can also be achieved by one or a combination of energy capture systems, such as:

- piezoelectric or triboelectric elements, which store energy from the movement of the human body;
-radio frequency (RF) energy harvesting, which requires an RF source to be close to the carrier;
-solar energy harvesters, where energy can be collected at certain times of the day or combining these harvesting methods with one of the energy storage devices.

Compared to other methods, harvesting mechanical energy using piezoelectric or triboelectric nanogenerators is the most widespread harvesting method available in all living environments, including our bodies. The energy collected by the energy capture methods mentioned above can be converted into useful electrical energy. However, they present several disadvantages, such as more space, similar to traditional energy storage devices (figure 1), which contain a container, cathode, separator, anode, electrodes, electrolyte and collector, also needing a component rigid electronics that limit the flexibility of the smart fabrics they power. Energy collection and storage systems based on textiles could be the best alternative for powering small e-textile devices if they ensure the required energy performance (figure 2).

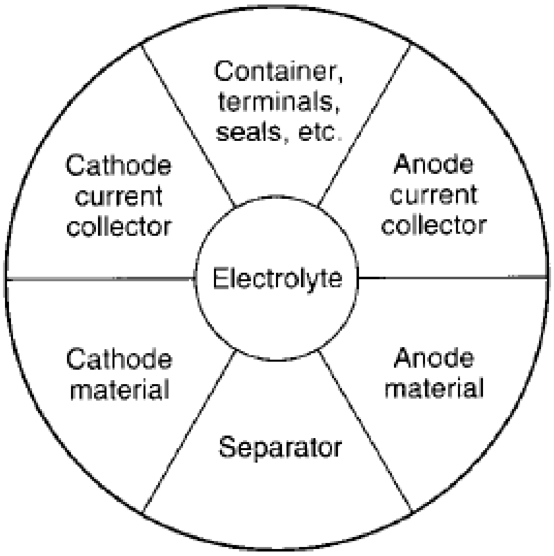

Fig. 1. Cell battery components [5]

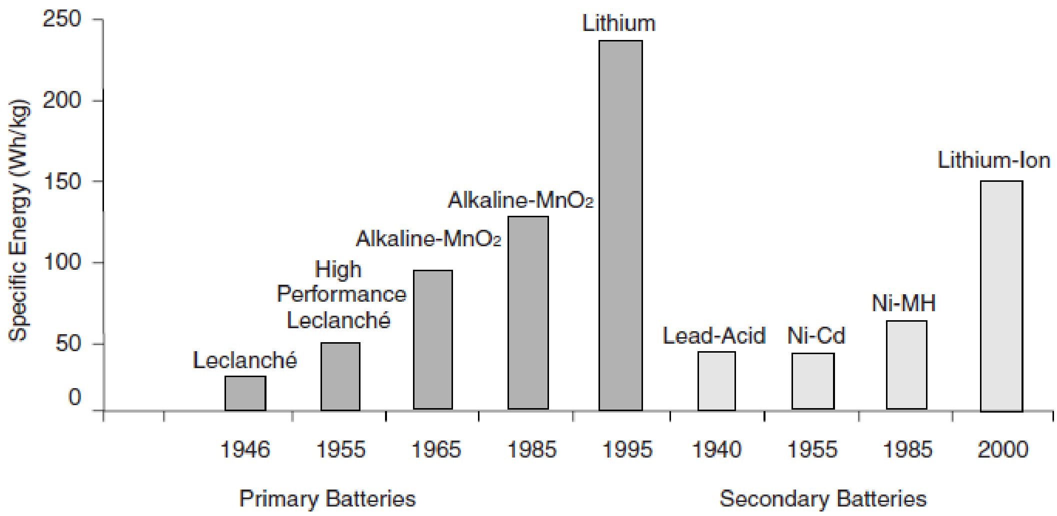

Fig. 2. Batteries performance for portable applications [5]

3. TYPES OF BATTERIES

3.1. Printed batteries

Printed batteries are of increasing interest to research and industry because they are ultra-thin, lightweight and have a low environmental impact. The individual components of the printed battery, including an electrolyte or separator, electrodes and current collector, must be manufactured using printing technologies.

Electrode design and battery architecture are crucial to producing an efficient battery. The two most common printed battery designs are stack or sandwich with coplanar or parallel architectures. The stacking architecture consists of two electrodes, a current collector for each electrode and an electrolyte separator, all printed on flexible support materials of specific thickness. Lithium-ion and alkaline zinc-dioxide manganese batteries are the most popular batteries made by 3D printing technologies [6]. Stack architecture is frequently used for lithium-ion batteries because it leads to low internal impedance due to the short distance the ions travel between the two electrodes.

On the other hand, the coplanar architecture, which consists of the two electrodes placed in a side-by-side arrangement, as opposed to the sandwich type, is frequently applied in the design of expandable batteries. The overall flexibility of the battery is based on the mechanical properties of the separate components [4].

3.2. Li-ion batteries

Due to their design and composition, lithium-ion batteries enable the production of reliable, low-cost, high-capacity energy sources. For Li-ion batteries to be suitable for smart textiles, ideally, such batteries should be flexible and not contain any liquid electrolyte [3].

Lithium-ion batteries are the latest in rechargeable battery technology and their market potential is proliferating with increased levels of investment in various value chains worldwide. Lithium rigid batteries produced in metal foil materials are powerful and greatly influence battery technology for various applications due to their high energy density and longer discharge life. In the last ten years, there have been achievements for the development of flexible lithium-ion batteries; however, due to the limited capacity and high mass per unit volume of the electrode materials, increasing the energy density while maintaining the flexibility, weight, and charge/discharge cycle stability of the battery is still a challenge [4].

3.3. Alkaline batteries

To generate electricity, alkaline batteries are based on chemical reactions (1) between zinc (anode) and magnesium dioxide (cathode) and the alkaline electrolyte potassium hydroxide (KOH). These batteries develop a specific energy of 145 Wh/kg and a specific density of 400 Wh/L [5].

$$Zn + 2MnO_2 \rightarrow ZnO + Mn_2O_3 \quad \textbf{(1)}$$

The basic electrolytes for these chemical reactions are potassium hydroxide (KOH) or sodium hydroxide (NaOH).

The most commonly used alkaline batteries applied for smart textiles and wearables consist of zinc-manganese dioxide (Zn-MnO2) batteries and silver-zinc oxide (Ag2O-Zn) monovalent batteries [4].

3.4. Water-based Li-ion batteries

One way to mitigate the air and water sensitivity and flammability of LIBs is to replace flammable organic electrolyte solutions with aqueous electrolytes.

Transition metal oxides, such as those in conventional LIBs have been used as active electrode materials. Lithium intercalation was the charge transfer mechanism to both the positive and negative electrodes so that the battery would perform the same way as conventional LIBs [7].

3.5. Metal-air batteries

Metal-air batteries are those in which oxygen from the ambient air is reduced, with the help of a catalyst, at the cathode during discharge [8].

Concomitant, the metal anode is oxidized, and the reactions of both electrodes can be reversible, forming a rechargeable battery. Rechargeable metal-air batteries can be composed of many different metal-electrolyte-catalyst compositions, aqueous or non-aqueous, and are seen as a promising technology due to their high theoretical energy density.

Metal-air batteries can be an attractive option to textile batteries because they are meant to be exposed to air and are insensitive to moisture.

Non-rechargeable zinc-air batteries have been widely commercialized for medical, military and industrial applications. They are considered the ideal power source for hearing aids due to their high volumetric energy, low cost and environmental friendliness.

Aluminium-air batteries produce electricity through the chemical reaction of oxygen in the air with aluminium and have been intensively researched due to their high theoretical capacity and energy. They were mainly considered for military and niche applications. However, there have been limited applications due to technical challenges, including anode corrosion, inability to reach theoretical voltages, water consumption during discharge, and lack of rechargeability [5].

4. CONCLUSIONS

Wearable batteries have essential requirements, such as flexibility, lightness and convenience. However, powering them remains challenging despite advances in the development of wearable and textile electronic devices. Actually, the power supply devices are typically built from rigid and bulky materials and often require more space than those they power.

Therefore, ensuring the supply of electrical energy and the efficiency of electrical energy consumption for flexible textile electronic devices is essential.

In conclusion, batteries and accumulators have significant potential in the textile field. From improving the performance of textile materials to developing smart fabrics that can monitor human health and provide electricity, textile batteries represent a new frontier of innovation in textiles and electronics.

ACKNOWLEDGEMENTS

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ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

PHYSICAL AND MECHANICAL CHARACTERIZATION OF COSMETIC TEXTILES WITH ANTI-ACNE EFFECT

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Abstract: *Functionalized textiles are rapidly becoming a promising area of research because of their potential applications in a variety of fields, including biomedicine, environmental protection, and consumer products. One of the most promising methods for functionalizing textiles is the use of dispersions. The use of dispersions containing natural products such as plant extracts and clays can also provide additional benefits such as sustainability and environmental friendliness. In this study, we have dealt with the physical-mechanical characterization of cotton fabrics treated with two different dispersions. The dispersions used contain a combination of freeze-dried plant extracts such as propolis, aloe vera, calendula, plantain, and blue clay. A cosmetotextile product should have physical-mechanical properties that allow the user to wear it comfortably and obtain the desired benefits. First, contact angle analysis was used to investigate the textile's ability to absorb liquids. Second, resistance to acid and alkaline perspiration was analysed to determine the durability of the applied finishing treatment using a SEM in conjunction with a EDS. Finally, a water vapor transmission analysis was performed to determine the extent to which the treatment affects the breathability of the textile.*
Overall, these analyses provide information for the development of functionalized textiles and demonstrate the potential benefits of using dispersions containing natural products in textile treatment.
Our study is part of a larger project to develop new functionalized textiles with improved efficacy in curing certain forms of acne. Therefore, further testing of the antimicrobial activity of the treated textiles will be conducted as the ultimate goal is to validate the product: Toxicity tests on various primary cells and macrophages, as well as in vitro tests on wound infection.

Key words: *antibacterial, functionalized textile,* lyophilized extract, dispersion, blue clay.

1. INTRODUCTION

In today's world, textiles have become an essential part of our lives, and the demand for fabrics with additional functions has increased tremendously. Recently, a new category of textile materials has emerged with specific applications in the cosmetic field. This has led to the development of a wide range of cosmetic textiles that are now available on the market.

Textiles are an important interface between people and their environment and can provide a sense of protection and comfort. There are two main methods for the production of cosmetotextiles: the bonding of microencapsulated cosmetic components onto textiles and the coating of textiles with active finishes [1].

Chemical finishing of textiles involves the application of chemical substances that can confer various functions or properties and can be applied in the form of an aqueous solution or emulsion by various techniques. Of course, in all these treatments, their ecological character must also be evaluated [2]. Apart from being effective against microorganisms, any antibacterial treatment of a textile material should be non-toxic to the consumer and the environment [3]. Functionalization of textiles can be achieved by printing processes, film production, incorporation, fulmination, etc. [4]. Innovative techniques bring the application of chemicals, new alternative carriers such as microencapsulation. These alternatives are very important today, especially when a long-term effect or controlled release of chemicals is desired. The advent of nanotechnologies also offers a wide range of new possibilities in the field of functionalization of textiles [5,6].

Both dispersions used to treat the textile material consist of natural compounds. For example, the blue clay is 100% natural, according to the manufacturers. The analyzes of the mineralogical content carried out at MINESA Mining Research and Design Institute in Cluj Napoca have revealed the high content of silicates and oxides, but also of minerals and trace elements such as calcium, magnesium, potassium, iron, silicon, cobalt, sodium, etc. Blue clay can be used as: antiseptic, antibacterial, antifungal, and anti-inflammatory [7].

One of the lyophilized plant extracts used is propolis. Propolis has a complex chemical composition, and therefore has both antibacterial, antifungal, antiviral, antiparasitic, anti-inflammatory, and antioxidant properties [8,9,10,11].

Aloe vera is a very effective plant for treating epidermis problems and healing superficial wounds. Due to its anti-inflammatory and bacterial properties, it is also used to combat acne by reducing or even eliminating acne pimples [12,13].

Calendula is a medicinal plant with a very ancient history that plays an important role in skin care, healing eczema, wounds, sunburn, or stings [14].

Several studies have shown that plantain is effective as a wound healer as well as an anti-inflammatory, antibacterial and antiviral agent. Moreover, plantain is a good antioxidant and an ally against free radicals [15].

2. MATERIALS AND METHOD

2.1 Textile functionalization

The chosen textile material is a fabric made of 100% cotton (CO), because it is available on the market, has low acquisition costs, but also because of its multiple properties. The following dispersions were used to treat the materials:

- Dispersion 1, consisting of distilled water, lyophilized extract (1 g/L), blue clay (1 g/L) and DMSO (10%)
- Dispersion 2, prepared from distilled water, lyophilized extract (1 g/L), blue clay (1 g/L), nano-halloysite (1 g/L) and DMSO (10%)

The binder Itobinder AG was used to fix the blue clay and nano-halloysite to the textile support. The sample codification is displayed in Table 1.

Table 1: Codifications used for the treated cotton fabric

Sample	Composition of treatment bath
$\mathbf{CO_{I.D1}}$	Dispersion 1
$\mathbf{CO_{I.D2}}$	Dispersion 2
$\mathbf{CO_{II.D1}}$	Dispersion 1

	Itobinder AG 20 g/L
$CO_{II.D2}$	Dispersion 2
	Itobinder AG 20 g/L
$CO_{III.D1}$	Dispersion 1 improved with Itobinder AG 20 g/L
$CO_{III.D2}$	Dispersion 2 improved with Itobinder AG 20 g/L

The untreated textile (initial) has been noted with: Fabric 100% Cotton – $CO_{initial}$.

2.2 Sample characterization

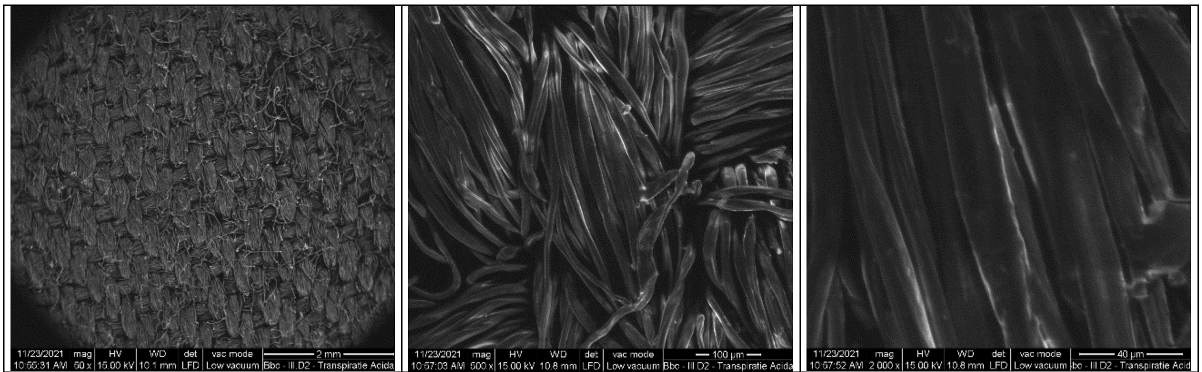
Resistance to acid and alkaline perspiration

The samples were cut into squares of 5 × 5 cm and placed in vials containing acid or alkaline sweat solution (the composition of these solutions is given in Table 2) for 30 minutes at room temperature, stirring the textile material periodically to wet it. The ratio is 50 ml solution /1 g sample.

After 30 minutes, the sample was dried on a flat surface. Resistance to acid and alkaline sweat was evaluated by electron scanning microscopy combined with dispersive X-ray spectroscopy (Figure 1 and Figure 2).

Table 2. Composition acid and alkaline sweat solution

Acid sweat solution pH = 5,5	**Alkaline sweat solution pH = 8**
0,5 g L-histidine monohydrate	0,5 g L-histidine monohydrate
5 g sodium chloride	5 g sodium chloride
2,2 g monosodium hydrogen phosphate	5 g disodium hydrogen phosphate



50×	500×	2000×

Fig. 1: SEM Images for $CO_{III.D1}$ sample- after acid perspiration

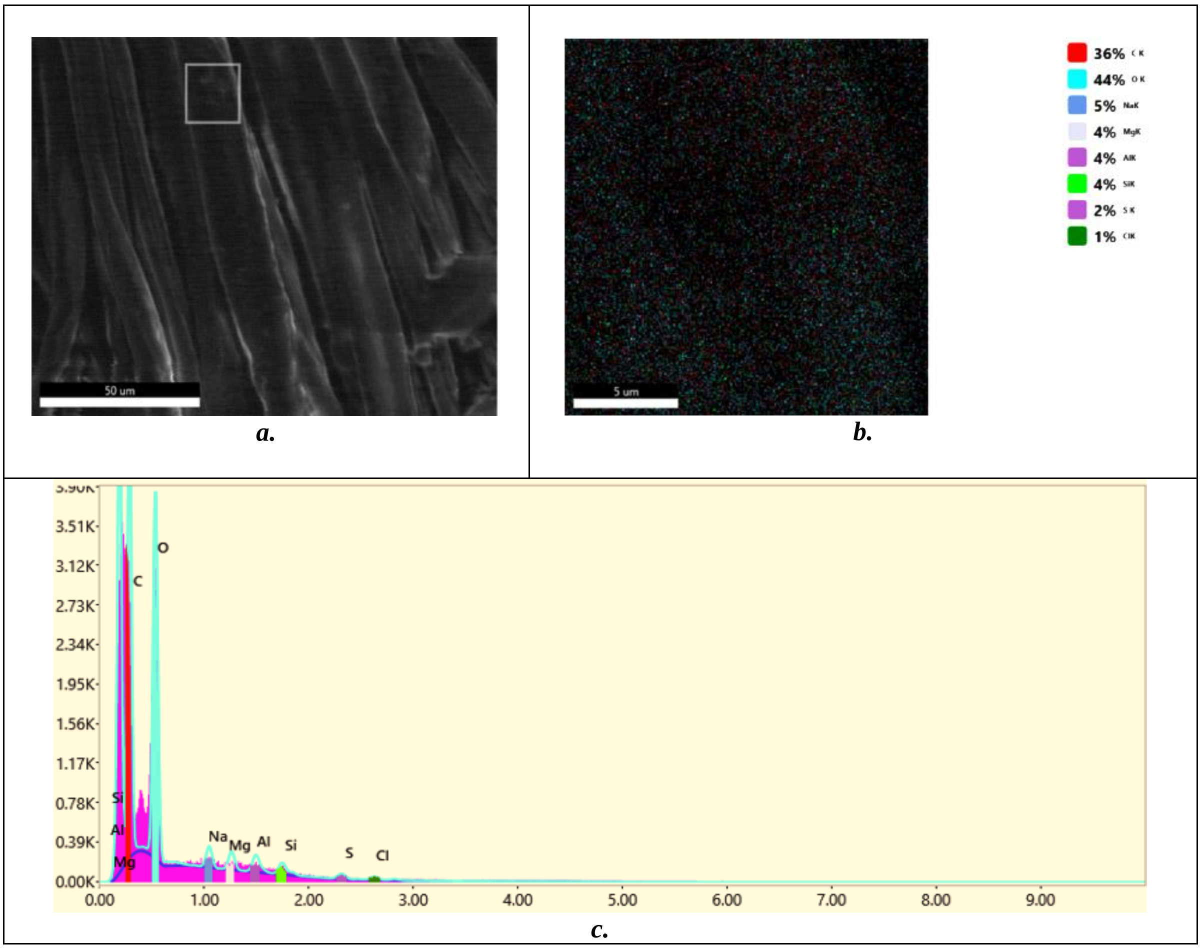


Fig. 2: EDS Results for $CO_{III.D1}$ sample - after acid perspiration - a. analyzed microscopic area; b. overlapping of the analyzed element/zone; c. EDS spectrum.

Water vapor permeability

The standard STAS 9005:1979 "Determination of water vapor permeability" has been used to assess the permeability of water-treated textile materials [16].

Mean results of the experimental values are shown in Table 3.

Tabel 3: Water vapor permeability results for cotton samples (%)

$CO_{initial}$	24,7
$CO_{I.\ D1}$	24,1
$CO_{II.\ D1}$	26,1
$CO_{III.\ D1}$	24,9
$CO_{I.\ D2}$	25,5
$CO_{II.\ D2}$	25,3
$CO_{III.\ D2}$	27,0

The highest value obtained was for sample $CO_{III.D2}$, which was 27%. This increased by 2.3% compared to the water vapor permeability obtained on the initial fabric.

Contact angle

The test was performed to evaluate the effect of treatment on the hydrophilic/hydrophobic properties of the original textile materials.

All treated cotton samples had angles less than 90°, so the material is considered hydrophilic.

3. CONCLUSIONS

In this study, laboratory experiments were conducted on the technological processes of deposition of dispersions of bioactive compounds with blue clay on a cotton textile material. The resulting functionalized textile was evaluated physically and mechanically.

Thus, one type of fabric was functionalized by the fullardation process (dispersion impregnation only, dispersion impregnation and dry impregnation with Itobinder AG 20g/L and modified dispersion impregnation with Itobinder AG 20g/L).

After the applied treatments, except for sample $CO_{I.D1}$, where the water vapor permeability decreases very slightly, the values of this parameter increase compared to the initial material, indicating a positive contribution of the treatment products, since they increase the breathability of these materials. The higher the value of this parameter, the more the product allows water vapor to pass through, which increases comfort.

The treatments applied to the textile materials do not affect the hydrophilicity or hydrophobicity of the starting materials, which retain their properties.

The materials treated and after exposure to acid and alkaline sweat solutions showed the following behaviour.

- all cotton samples have the elements included in the composition of the applied treatments (Al, Si, Na, Mg, Fe). Of these, in the case of $CO_{I.D1}$, $CO_{II.\ D1}$, $CO_{II.\ D2}$ and $CO_{III.D2}$ (example in Figure 1 and Figure 2), the elemental composition of the dispersions was the best preserved (most of the elements of the clay composition used in the dispersion are present).

- the action of acid and alkaline sweat solutions on the treated samples does not affect the element concentration of the main components, which indicates that the applied final treatment is resistant to these solutions.

Against the backdrop of an increased trend towards treatments based on high quality products made from plant extracts and functional textiles that come into contact with human skin, the research carried out brings added value in these areas.

With this research, we aimed to contribute to the development of sustainable and effective solutions for the control of bacterial infections and to open new opportunities for the development of alternative therapies.

It is proposed to continue the work with tests for product verification and validation: Toxicity tests on various primary cells and macrophages and in vitro tests for wound-specific bacteria, but also tests of textiles from antimicrobial and physicochemical points of view.

ACKNOWLEDGEMENTS

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RENEWABLE COMPOSITES BASED ON OAK ACORN EXTRACT, COLLAGEN AND WHEY, WITH APPLICATIONS IN LEATHER PROCESSING

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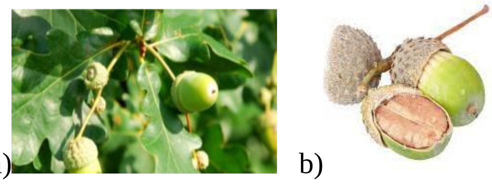
Abstract: *This research elaborated novel biotechnologies for including active substances from oak acorn extract, collagen and whey, and glyceraldehydes, obtaining novel stable systems-bioactive compounds, with application in leather processing. The bioactive composites with different concentrations of oak acorn extract, collagen hydrolysate processed from leather waste, and whey were used with or without glyceraldehydes for sheepskin tanning. The new biocomposites and processed leathers were characterized by physical-chemical microscopy and spectral methods. The characterizations allowed selecting the suitable technology for skin processing as a potential alternative to classical technologies. The composites with higher concentrations of acorn extracts in combination with glyceraldehyde showed the best performances in collagen crosslinking. We estimate that the new ecological leathers processed with renewable materials will generate biodegradable waste and leather products with wearing durability and higher biodegradability at the end of their life cycle.*

Key words: *renewable compounds based on oak acorn extract, collagen and whey; innovative biotechnologies; leather processing in leather industry*

1. INTRODUCTION

The oak is part of the *Fagaceae* family and is widespread in the temperate climates of Europe, Asia and some regions of North Africa. In Romania and Serbia, it is found mainly in plain and hilly areas, in meadows, and depressions. The oak blooms in May, its flowers are monoeciously arranged in catkins. Its fruits are achenes, are called acorns, and grow in groups of 2-5 on a peduncle (Fig.1). The acorn seed is known as a high-calorie nutrient (339 kcal/100 g), rich in vitamin C, magnesium, and calcium, and is still used for the preparation of traditional “acorn coffee”.



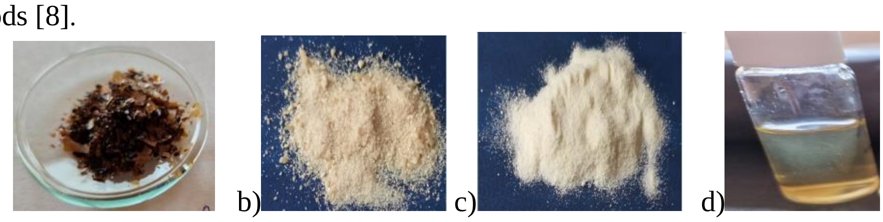
a) b)

Fig. 1: Oak acorn (a) and seed acorn (b) [1]

Other active substances found in oak acorn are quercitanic acid, ellagic and gallic acid, bitter principles, tannin, quercin, fluroglucin, pectic substances, resins, calcium oxalate, pentadigalloylglucose, cyclogallifaric acid and carbohydrates. These give them astringent, antiseptic, surface hemostatic, anti-inflammatory, antioxidant [2,3] and deodorant effects. The interest in sustainable raw materials and alternatives to wood-origin tannins with a negative impact on ~~forest~~ deforestation oriented the research to tree and bush fruits rich in tannin like oak acorn, tara pods, and sea buckthorn branches [4-6]. The novelty of this work is represented by the combination of collagen hydrolysate and whey powders, with vegetable ones from oak acorn extract, and the formulation as a renewable composite with tanning and filling properties. The other renewable materials were the glyceraldehydes prepared from glycerin, another sustainable raw material, by catalytic oxidation. The new composites based on oak acorn extract, collagen hydrolysate whey and glyceraldehydes were characterized by physical-chemical methods, UV-VIS and FTIR-ATR spectroscopy, dynamic light scattering, and optical microscopy. The new composites experimented for skin tanning in combination with two types of glyceraldehydes for designing biodegradable leathers with ecological impact on the environment for leather waste and leather products.

2. MATERIALS AND METHODS

The following renewable raw materials have been used: acorn seed powder (Skap, Kosmaj, Serbia), leather waste (ICPI plant production), whey powder (Managis Serv SRL, Romania), and glycerine. The acorn powder has a composition of 57% carbohydrate, 5.14% protein, 5.14% fat, and traces of phosphorous, potassium, calcium, magnesium, manganese, and iron. The acorn seed extract was prepared by boiling the acorn seed powder in water, at 90°C, for 1 hour. The extract was separated from the residue by centrifuging for 30 minutes and was dried in an oven at 60°C (Fig.2.a). The collagen hydrolysate was prepared by the chemical-enzymatic method, according to our previously published papers [7]. The main characteristics of collagen hydrolysate (Fig.2.b) are 10% volatile matter, 94.06 % protein substance, pH of 4.40 (10% dispersion). The composition of whey powder (Fig.2c) is 13.3% volatile matter, 72% carbohydrate, 12.5% protein, 0.7% fat, and 1.5% salts. The glyceraldehyde (Fig.2d) was prepared by catalytic oxidation of glycerin according to literature methods [8].



a) b) c) d)

Fig. 2: The images of a) acorn seed extract, b) collagen hydrolysate,
c) whey powder and d) glyceraldehyde

The renewable composites were prepared by mixing the collagen hydrolysate with whey and acorn seed extract for 4 hours at 45°C, followed by oven drying at 60°C and solid composites ball milling. Three different concentrations of acorn seed extracts were used and three composites were obtained, SZC1, SZC2 and SZC3 (Fig 3).

a)  b)  c) 

Fig.3: New composites for skin tanning: a) SZC1, b) SZC2 and c) SZC3

The new products were characterized by physical-chemical methods (SR EN ISO 4684: 2006 for volatile matter, SR EN ISO 4047: 2002 for total ash, SR ISO 5397: 1996 for protein substance, STAS 8619/3:1990 for pH, and Folin Ciocalteu method for total phenols), optical microscopy (confocal optical microscopy with 532 nm -CW, 636 nm -CW or ps-mode and 774 nm-120 fs excitation sources), UV-VIS (GBC,model 918) and FTIR-ATR spectroscopy (Thermo Scientific™ Nicolet™ iS50 FTIR-ATR), dynamic light scattering (Zetasizer-Nano ZS MALVERN).

3. RESULTS AND DISSCUSSION

The main physical-chemical characteristics of new composites are presented in Table 1.

Table 1. Physical-chemical characteristics of composites SZC1, SZC2, and SZC3

Characteristics	Values		
	SZC1	**SZC2**	**SZC3**
Volatile matter, %	7.04	7.44	7.83
Total ash, %	4.01	4.89	5.5
Protein content, %	20.30	22.50	23,80
pH 1:10, pH units	4.9	4.6	4.5
Total phenols, mg catechin /100 g product	0.035	0.056	0.065

The physical-chemical characteristics showed that the total phenols content is low as compared to the protein content due to the protein content of all components, collagen hydrolysate, whey, and acorn seeds. The UV-VIS spectra of 0.3% solutions of composites and components are presented in Figure 4. The FTIR-ATR spectra of solid samples of SZC1, SZC2, SZC3, collagen hydrolysate, whey, and oak acorn seed extract are illustrated in Figure 5.

An interaction between oak acorn seed extract and collagen is observed in the powders, the most obvious being for the highest content of oak acorn seed extract-SZC3 in the field of 1000-1500 cm^{-1}, and for 3000 cm^{-1}, specific wavenumbers for oak acorn seed extract The FTIR spectrum of glyceraldehyde (not shown here) allowed identifying the absorption-specific peaks of 1419 cm^{-1}-1043 cm^{-1} wavenumbers and of C=O groups at 1400 cm^{-1}, which confirmed the conversion of hydroxyl groups into carbonyl groups.

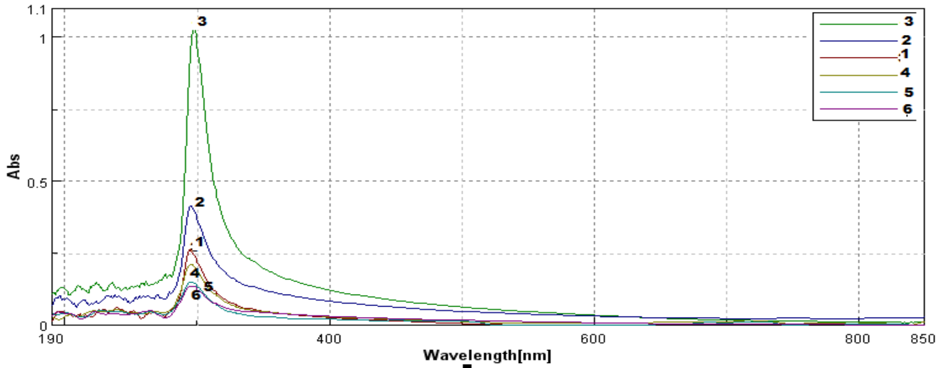


Fig. 4: The UV-VIS spectra for samples: **1**-SZC1, **2**-SZC2,**3**-SZC3,
4-Collagen hydrolysate, **5**-Whey, **6**-Oak acorn seed extract

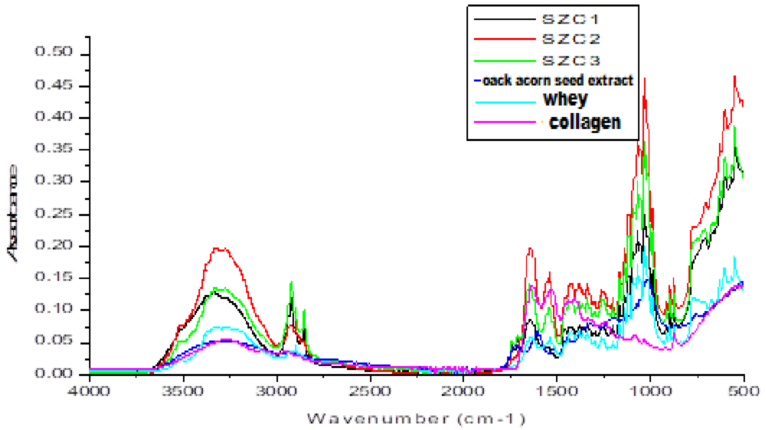


Fig. 5: The FTIR-ATR spectra of powder samples: **1**-SZC1, **2**-SZC2,**3**-SZC3,
4-collagen hydrolysate, **5**-whey, **6**-oak acorn seed extract

The average particle size, polydispersity, and zeta potential of new composites and glyceraldehyde are presented in Table 2 and can give information on particles' ability to interreact with skin. The increase of the concentration of oak acorn seed extract has an influence on composite average particle size and polydispersity, premises for collagen binding. The opposite charges of composites and glyceraldehyde suggests a good combination for skin tanning.

Table 2. The average particle sizes, polydispersity, and zeta potential of SZC composites, and glyceraldehyde

Tanning product	Average particle size, nm	Particle sizes, nm /share, %	Polydispersity	Zeta potential, mV
SZC1	561.30	479.56/85.36	0.497	-24.5
		79.30/21.95		
SZC2	760.10	313.33/72.76	0.661	-25.7
		211.86/27.23		
SZC3	832.96	538.03/71.33	0.795	-22.8
		92.46/28.67		
Glyceraldehyde	585.60	544.70/79.00	0.489	11.78
		4227/21.00		

The optical microscopy of composite solutions confirmed the agglomeration of the particles of SZC3 particles as compared to the other composites (Fig. 6).

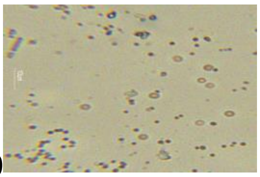
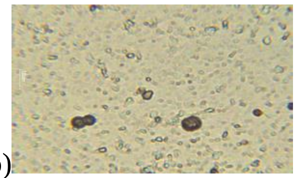
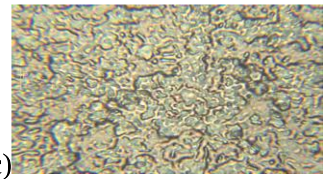
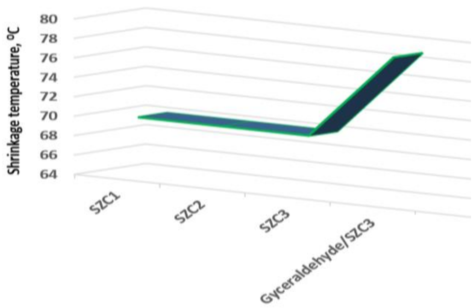
a)  b)  c) 

Fig.6: Optical microscopy images (1000x) for samples: a) SZC1, b) SZC2, c) SZC3 0.3% solutions

The experiments on sheepskin tanning with new composites and combinations of composites and glyceraldehyde showed that the combination of composite SZC3 and glyceraldehyde allowed suitable crosslinking of the collagen (Fig.7a).



a)


b)

Fig.7: The shrinkage temperature of tanned sheepskins with SZC composites and combinations with glyceraldehyde (a) and sheepskin samples (b).

The FTIR-ATR spectra of tanning composites: SZC1, SZC2, SZC3 and tanned sheepskin leathers processed with different combinations are illustrated in Figure 8.

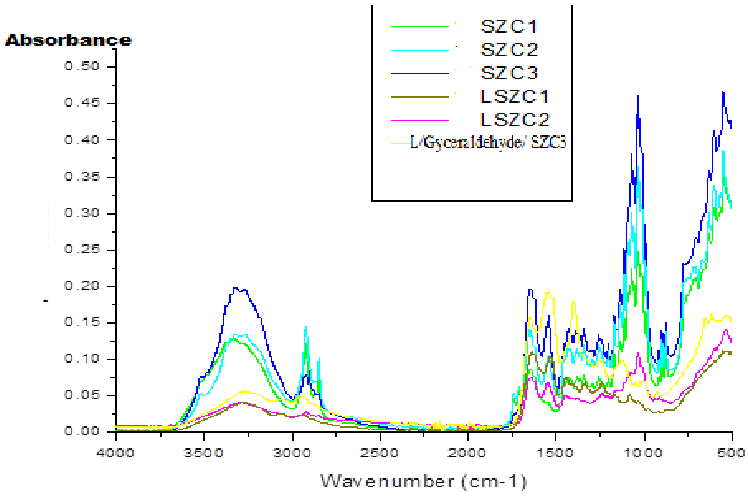


Fig. 8: The FTIR-ATR spectra for composite powders and tanned sheepskin leathers:
1-SZC1, **2**-SZC2,**3**-SZC3, **4**-LSZC1, **5**-LSZC2, **6**-L/Gyceraldehyde/ SZC3

Fig.8 showed an interaction between acorn oak extract and leather, highlighted by a maximum at the wavenumber =3000 cm^{-1}, specific oak acorn seed extract (Fig.5). The strongest interaction between oak acorn seed extract and leather occurs for the combination of gyceraldeyde with SZC3, LGlyceraldehyde/SZC3.

The potential of using renewable composites and combinations with ecological aldehydes were suggested as alternative for lower biodegradable commercial technologies and materials. Further investigations will be continued to improve tanning and material characterization in order to optimize products.

4. CONCLUSIONS

In this research were created novel biotechnologies for including active substances from oak acorn seed extracts, collagen hydrolysate, whey, and glyceraldehyde, as ecological, renewable alternatives for lower biodegradable commercial products.

The composites based on oak acorn seed extract, collagen hydrolysate and whey (SZC1, SZC2, SZC2), and the glyceraldehyde, were characterized by: UV-VIS and FTIR-ATR spectroscopy, dynamic light scattering and, optical microscopy, showing the increase of the particle size of composites with acorn seed extract concentration. The experiments on sheepskin tanning showed that the combinations of glyceraldehyde and SZC3 composite allowed crosslinking of collagen and offer a potential ecological tanning alternative. The particle size, zeta potential values as well as the ATR-FTIR analyses confirmed the conclusions of the research which will continue with tanning optimization and leather characterization.

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ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

EVALUATION OF THE RELATIONSHIP BETWEEN ELASTIC AND ELECTRICAL CHARACTERISTICS OF CONDUCTIVE TEXTILES

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Abstract: *Smart textiles are fabrics that interact intelligently with nearby surroundings or consumers. The electronic textile (e-textile) can sense environmental circumstances or stimuli and provide information that can effectively respond to and adapt actions. An electrically conductive textile is a piece of smart textile that incorporates conductive fibres, yarns, fabrics, and ultimate products. Conductivity is one of the properties that allow the integration of textiles in electrical circuits to ensure the functionality of electronic devices. The integration of conductive yarns in a structure is a complex and seldom a uniform process as it needs to be ensured that the electrically conductive fabric is comfortable to wear or soft to touch rather than hard and rigid. The paper presents an original method for determining the relationship between the conductivity of conductive textile structures and their elastic characteristics. Statex and Bekinox conductive yarns of fineness 296-610 dtex were used to make woven and knitted structures. The SEM and EDAX analyses of the wires were carried out on the Scanning microscope Quanta FEI 200. The physical-mechanical characteristics analyzed highlighted: strength (N) and elongation at break (%), tear resistance (N), resistance to deformation (kPa) and deformation (mm) of the conductive structures. The modulus of elasticity (N/cm^2) and anisotropy was calculated. The correlation coefficients between the three variables have high values (>0.980). The Lloyd material testing equipment coupled with a data acquisition unit-DAQ (white box) was used for the simultaneous variation of elasticity and electrical conductivity of textile structures.*

Keywords: *textile, conductivity, elasticity, deformation, correlation*

1. INTRODUCTION

Conductive yarns and fabrics are specialized textile materials that are made by incorporating conductive materials such as metals, carbon nanotubes, or conductive polymers into their structure [1]. These materials have the ability to conduct electricity and can be used in a wide range of applications such as wearable technology [2, 3], smart textiles [4], electromagnetic shielding [5] and electronic devices [6]. Conductive materials are being increasingly used in specialized clothing to create high-performance garments that are both comfortable and functional, allowing the garment to interact with its environment and enhance its capabilities [7]. Conductive fabrics can undergo mechanical deformation, which can affect their electrical properties. Mechanical deformation refers to the change in shape or size of the fabric due to external forces, such as stretching, compression, bending, or twisting. When conductive fabrics are subjected to mechanical deformation, their electrical resistance can change [8]. This is because the deformation can cause the conductive fibres/yarns in the fabric to move or reorient, which can change the path of the electrical current flowing through the fabric. As a result, the electrical conductivity of the fabric can either increase or decrease, depending on the nature and extent of the deformation. Stretching a conductive fabric can cause the component yarns and fibres to align in the direction of the stretch, which can increase the conductivity of the fabric along that direction [9]. On the other hand, compressing or twisting the fabric can cause the fibres to become more compacted, which can decrease the conductivity of the fabric. Understanding the mechanical behaviour of conductive fabrics is important for designing and engineering wearable electronics and smart textiles, where the fabrics are often subjected to a range of mechanical deformations during use. By characterizing the electrical response of conductive fabrics to different types and levels of mechanical deformation, designers can optimize the performance and reliability of their products. In general, conductive fabrics can have two types of stretching properties: mechanical stretching (the ability of the fabric to stretch and deform under mechanical stress, such as when it is pulled or bent) and electrical stretching (the ability of the fabric to change its electrical properties when it is stretched) [10]. The stretchable properties of conductive fabrics can vary depending on the specific material, composition, and manufacturing process. Several studies have investigated the effect of mechanical deformation on the electrical properties of conductive fabrics. A study found that stretching a conductive fabric along one direction increased its conductivity along that direction while reducing it perpendicular to the stretch. Another study examined the effect of bending on the electrical properties of conductive fabric. However, the extent of the change varied depending on the direction and degree of bending, suggesting that the behaviour of conductive fabrics under mechanical deformation is complex and highly dependent on specific conditions [11]. The paper presents an original method for determining the relationship between the conductivity of conductive textile structures and their elastic properties. The electrical resistance is stable for up to 40% strain, especially for the woven fabric sample, compared to the knitted fabric samples.

2. MATERIALS AND METHODS

The conductive yarns and the textile yarns Statex (Ag/PA)-Cotton-610 dtex, Statex (Ag/PA) -PES- 610 dtex and Bekinox-PES-400 dtex were used to obtain conductive fabric structures. Classic/conventional technologies of weaving and knitting were applied to provide two variants of knitted structures (A4-jerse, C5-interlock and C6 patent) and a variant of woven structures (B4-plain). The physical-mechanical characteristics of the analyzed textile structures highlighted: resistance (N) and elongation at break (%), resistance to tearing (N), resistance to deformation (kPa) and deformation, and resistance to tearing (N). The SEM and EDS analyses of the yarns were carried out on the Auriga model workstation produced by Carl Zeiss SMT Germany FESEM FIB with field emission source with Gemini column for the electron beam that highlighted the arrangement of the component elements of the conductive yarns and the elemental analysis. The modulus of elasticity was calculated knowing the initial length (L) of the tensile test specimen, the applied force (N) and the elongation (%) at the transition point from the elastic zone to the plastic zone of the stress-elongation curve, the difference in length (ΔL), the thickness of the textile structures (mm), the area of the sample (cm^2). The ratio between the modulus of elasticity in the horizontal and vertical direction allowed for obtaining the anisotropy of the textile structures. The Solidwork program highlighted the contribution of conductive structures to stress. The correlation coefficients between the three variables were calculated. The Lloyd material testing equipment coupled with a data acquisition unit-DAQ (white box) was used for the simultaneous determination of the variation of strain and resistance of textile structures highlighted. A conductive fabric sample of 5cm by 20cm clamped between the jaws of a Llyod tensile machine set at gauge length 20. The fabric sample is also connected to the DAQ unit that continuously measures the electrical resistance of the fabric. The samples' cycling (loading and offloading) was performed at a 200 mm/min cycling speed. For a complete cycle, the fabric is loaded continuously to a specified per period for 2 seconds (relaxation) and then released centage releasing the load at the same speed as the gauge length. The strain was applied at 5%, 10% 15% 20% 30%, 40%, and 50%. Each sample was tested for 5 cycles, meaning loading and offloading 5 times. The first cycle was always strange for all the tests because the sample underwent a kind of pretension in the first cycle, thus the correct measurements always start in the second cycle.

3. RESULTS

Table 1 shows the main characteristics of the conductive yarns used to make textile structures and Fig.1 aspects of the longitudinal sections of the conductive yarns and the EDS diagrams that highlight the main compositional elements. The main characteristics of woven and knitted structures are presented in Table 2.

Table 1: Conductive yarns characteristics

No.crt.	Conductive yarn	Fineness, dtex	The apparent diameter, μm	Linear electrical resistance, Ω/m
1	Statex Ag/PA	610	284	76
2	Statex Ag/PA	296	228	220
3	Bekinox	Nm 50/2 (200 x 2 dtex)	273	2200

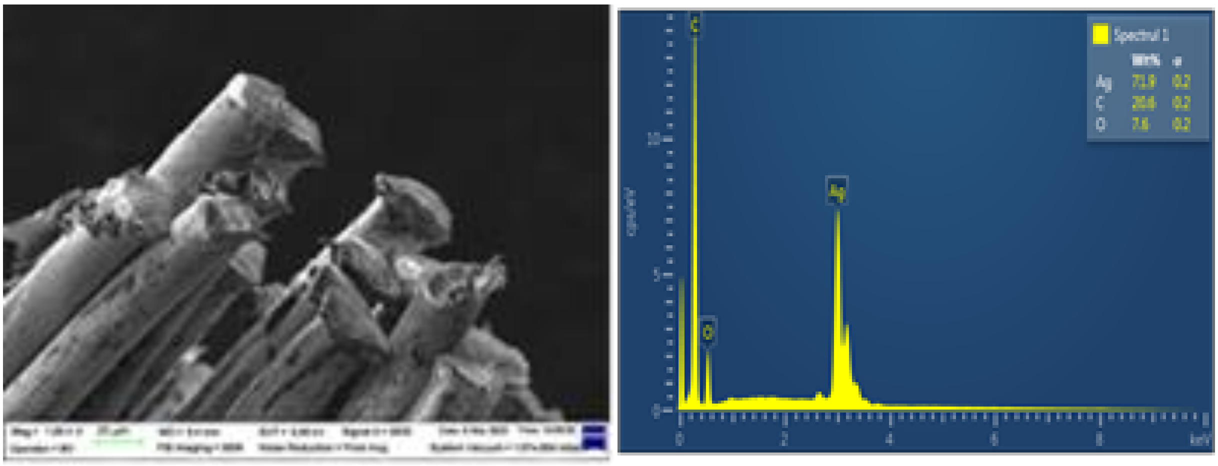
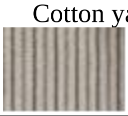
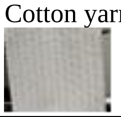


Fig. 1: SEM/EDS of a conductive yarn

Table 2: Conductive fabrics characteristics

Characteristics/Variant		Knit A4-jerse	Knit C5-interlock	Woven B4-plain	Knit C6 - patent
Mass/g/m^2		369,5	115	146	98,0
Length of metal yarn, cm/10cm		34	35	10,3	29,0
Yarn density, no./10cm	H	180	75	280	70
	V	48 Metallic yarns	40 Metallic yarns	44 Metallic yarns	46 Metallic yarns
		192 Cotton yarns 	50 Cotton yarns 	105 Cotton yarns 	90 Metalic yarn 
Breaking strength, N	H	617,8	431,54	1659,25	163,05
	V	539,8	234,40	764,69	197,73
Elongation at break,%	H	87,6	94,14	36,28	124,91
	V	113,3	171,64	22,28	92,89
Thickness, mm		1,57	0,96	0,49	0,56
Resistance to deformation	KPa	531,8	303,1	647,95	191,0
	mm	41,23	36,7	36,75	44,9
Tear resistance, N	O (Wa)	36,84	31,86	78,51	30,33
	V (Wf)	23,7	55,68	98,97	33,58

By applying its own procedure (INCDTP) the length of the conductive yarn, cm of yarn/10 cm of fabric in the textile structures was obtained and it varies from 10.3 cm/10 cm (B4) to 35 cm/110 cm (C5). The breaking force for knitted structure varies within the limits 163,5N (C6) – 617,8N (H) and 197,73N (C6)-539,8N (A4). The highest value of the elongations at the break on the horizontal direction is presented by C6 (124,91N) and for the vertical direction by C5 -171,64N. The woven structure (B4) is stronger than knitted structures (both directions) it has smaller elongation values. The knitted fabric with patent structure (C6) has the lowest resistance to deformation (191KPa) compared to the one with jerse structure (A4-531.8KPa) and interlock (C5-303 KPa). The higher density of the metal yarns but also the difference in the structure determines the high deformation of the A4 (41,23mm) and C6 (44,9mm) knitted variants compared to C5. The woven structures (B4) have the lowest value of the metallic yarn length, but the specific structure leads to a higher resistance of deformation (647,95) N against knitted structures and the lowest deformation (36,70mm). The Solidwork program was used to visualize the behaviour of the textile structures in the tensile strength test (Tinius Olsen dynamometer) (Fig.2). The increase in the applied force causes the colour regime to change from blue to red in the test piece's breaking area.

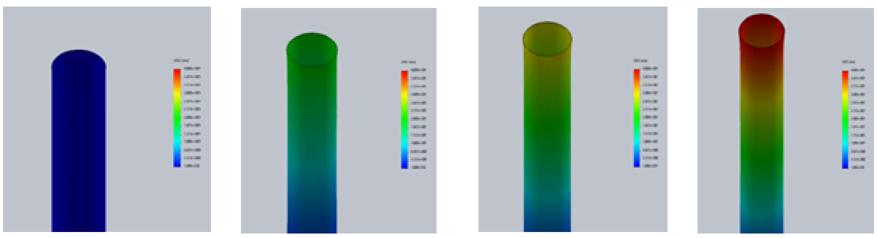


Fig.2: Visualization of stretching behaviour- variant A4

The elasticity module shows the lowest values for the C5 knit version, both in the horizontal direction (0.766 N/cm^2) and in the vertical direction (0.265 N/cm^2).

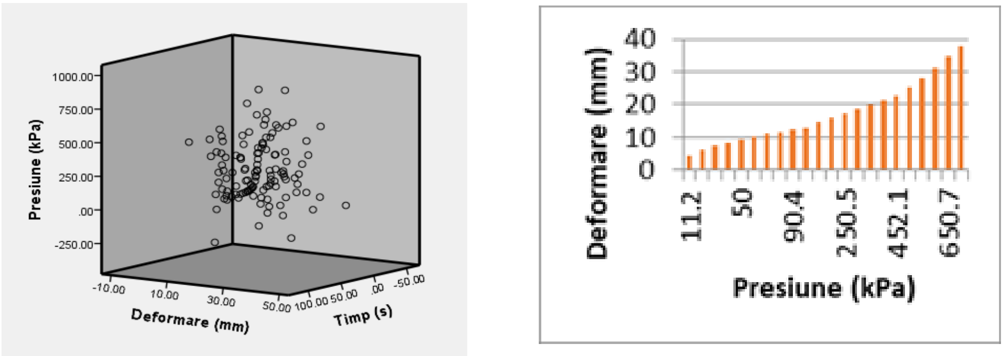


Fig. 3: Evolution of the deformation of textile materials depending on time and applied force-C5

The variant with the highest anisotropy is the C5 knit variant (2.89), which highlights different behaviour of elasticity in the two directions of the textile structure. The best anisotropy is presented by the woven fabric variant (0.42). A specialized professional program was used to highlight the evolution of the deformation of textile materials depending on time and applied force (Fig.3). The experiment set up of Lloyd materials testing equipment that is coupled together with a data acquisition unit-DAQ, the white box gives the relationship between the mechanical properties (strain/elongation/load), to electrical properties, the resistance of the conductive material. The measurements are determined simultaneously (Fig.4). The level of electrical resistance, force and strain variables at the beginning and the end of the strain 5% and 40% of the studied textile structures are presented in Table 3.

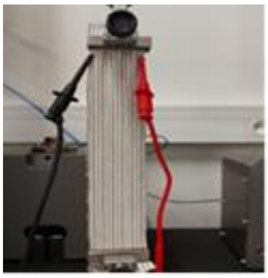


Fig. 4a) A4


Fig. 4b) C5

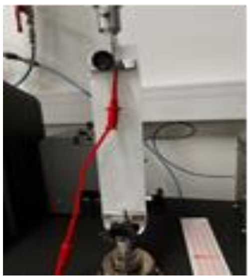


Fig. 4c) B4

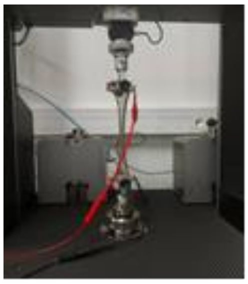


Fig. 4d) C6

Table: 3 Electrical resistance evolution

No	Samples	Time (s)	Resistance Ω	Load (N)	Strain	Observation
1	A4 (5%)	0,54	411,4	0,174	-0,004	Max.resistance:412,17 Ω/m at time:10,97 s, load:0,065N and strain: -2,4E-05
		51,56	410	-0,06	0,008	
	A4 (40%)	2,766	216,38	1,13	0,034	Max.resistance:425,7 Ω/m at time:193,75 s, load:76,39N and strain:0,4
		271,11	185,75	0,033	0,005	
2	C5 (5%)	1,66	417,06	1,04	0,004	Max.resistance:471 Ω/m at time:41,8 s, load:20,44N and strain:0,98
		142,26	276,79	-0,306	0,0097	

	C5 (40%)	2,68	410,42	0,541	0,007	Max.resistance:427 Ω/m at time:16,10 s, load:53,01N and strain:0,2122
		263,01	417,38	-0,401	0,048	
3.	B4 (5%)	0,844	427,7	0,71	0,0013	Max.resistance:429,65 Ω/m at time:50,68 s, load:0,387N and strain:1,08E-08
		82,78	425,52	0,403	7,57E	
	B4 (20%)	0,248	427,62	1,905	0,006	Max.resistance:433,36 Ω/m at time: 2,236s, load:0,516N and strain: -2,6-07
		12,67	427,05	242,26	0,173	
4	C6(5%)	0,53	7,55	0,37	1.53E	Max.resistance:12,18Ω/m at time:29,55s, load-0,259N and strain:0,0057
		52,66	12,38	0,2864	-1,08E	
	C6(40%)	2,73	21,20	1,231	0,022	Max.resistance:37,17 Ω/m at time:144,90s, load:0,791 and strain:0,311
		267,94	21,74	0,211	0,007	

The resistance of the fabrics that have in the structures metallic yarn and cotton yarn, changes between a minimum of 412,17 ohms/m (A4) to a maximum of 433,36ohms/m(B4) which **is within** the tolerable limits of the resistance of the conductive yarn of 76 ohm/m (yarn 1) – 220 (yarn 3) ohm/meter. The lowest value of the electrical resistance was obtained by the knit structure made only of conductive (yarn 1). In this case, the min./max value at the strain 5% was: 2,72 Ω/m/12,18 Ω/m and at the strain 40%:0,56 Ω/m/37,17 Ω/m. These values are in the limit of linear electrical resistance of the yarn (76 Ω/m).

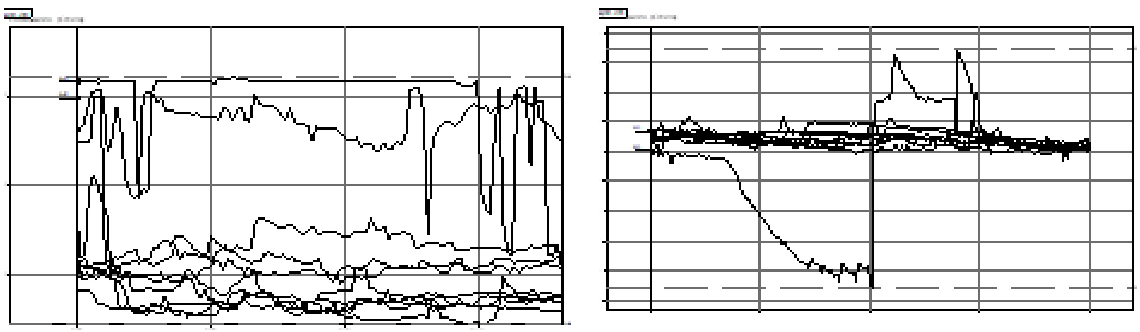


Fig. 5: The evolution of the electrical resistance (Ω/m) of sample C5 as a function of the applied strain of 5% and 40%

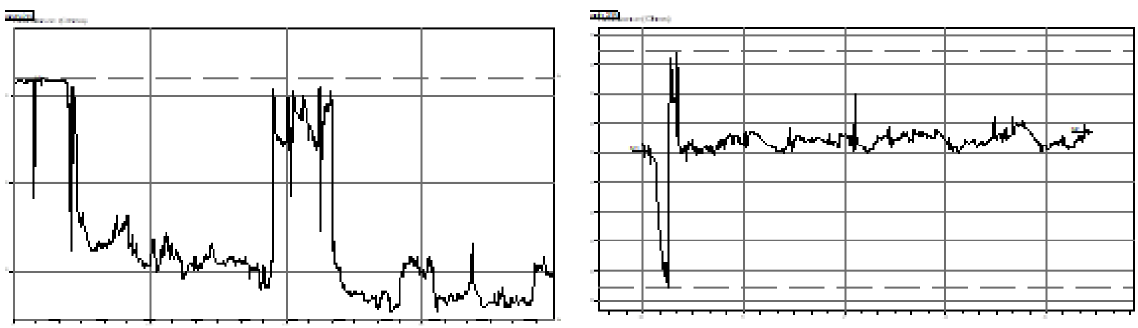


Fig.6: The evolution of the electrical resistance (Ω/m) of sample C5 as a function of the time at an applied strain of 5% and 40%

Fig. 5 shows the evolution of the electrical resistance (Ω/m) as a function of applied strain and fig.6 as a function of time for the C5 variant at an elongation at 5% and 40% and 5 cycles. There is some noise observed in the resistance measurements, due to the variation caused by the contact(s) resistance. The contact resistance is the resistance between two yarns in contact in the knit or the weave, these changes depend on the dynamics of the forces on the fabrics.

4. CONCLUSIONS

Conductive textile structures were made by using Statex yarns and Bekinox yarns (296-610 dtex) and applying classic knitting and weaving technologies. By using Lloyd materials testing equipment that is coupled together with a data acquisition unit-DAQ (white box) the evolution of linear electrical resistance (Ω/m) was obtained depending on the applied force and time. The electrical resistance of textile structures during deformation has higher limits compared to that of the constituent conductive threads. The lowest value of the electrical resistance was obtained by the knitted structure made only of metal conductive yarns. The electrical resistance is stable for up to 40% strain, especially for the woven fabric sample, compared to the knitted fabric sample. This aspect will be taken into account in the design of the new structures and in particular in the geometry of the insertion of the conductive wires and their structure also to avoid contact resistance between the yarns.

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CONTENTS

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