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Seersucker Woven Fabrics with Therapeutic Properties

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Abstract
Cellulite is a serious aesthetic and health skin problem. The term cellulite refers to the dimpled appearance of the skin on hips, thighs and buttocks. Most of the existing methods of reduction or prevention of cellulite require not only significant expense but, above all, time and regularity of use. Therapeutic clothing with anti-cellulite properties seems to be an optimal solution which could be applied during women's daily activity, simultaneously with business or housework. Such clothing, in addition to anti-cellulite properties, should have appropriate biophysical properties to ensure the wearers hygiene and physiological comfort. Within the framework of the research presented, an assortment of seersucker woven fabrics for anti-cellulite clothing was developed. Anti-cellulite properties of the fabrics developed were achieved through a three-dimensional structure of fabrics providing a massaging effect during the usage of clothing made thereof, the use of innovative yarns made of polymer fibres with antibacterial properties, and yarns providing moisture transport. In addition, thanks to the three-dimensional structure, the fabrics developed are characterised by an increased thermal resistance that provides a thermal effect, which is also an important element in the fight against cellulite.

Key words: *seersucker fabrics, therapeutic properties, antibacterial properties, micromassage, anti-cellulite clothing.*

Introduction

Cellulite is a condition in which the skin has a dimpled, lumpy appearance [1]. It is a serious aesthetic problem. Cellulite is also known as orange-peel skin, due to its texture. The term cellulite refers to the dimpled appearance of the skin on hips, thighs and buttocks.

Ca. 85% of post-pubescent females of all races display some degree of cellulite [2]. Cellulite can also affect men, but it is more common in females, due to the different distributions of fat, muscle, and connective tissue [1].

There are numerous anti-cellulite treatments available. According to research studies [3, 4], the best results can be achieved by such therapies as acoustic wave therapy, laser treatment, vacuum-assisted precise tissue release, ionithermie cellulite reduction treatments, etc. Existing anti-cellulite therapies, such as anti-cellulite creams and lotions, a low-fat diet, mechanical massages, laser or light therapy, and mesotherapy are expensive, and can only be used occasionally. Moreover the effects are very often mostly temporary.

The application of anti-cellulite cosmetics and massages requires not only significant expenditure but also, primarily, time and regularity. Frequently lack of time is the serious barrier to fighting cellulite. A lot of professional women over 35 are wives and mothers as well, who have to connect their family and professional duties. More and more women all over the world suffering from cellulite problems are looking for home-use convenient methods for reducing or even preventing cellulite. The optimal solution would be the method which could be applied during women's daily activity, simultaneously with business or housework. Such therapy can be ensured by anti-cellulite clothing.

Some kinds of anti-cellulite clothing are already present on the market. Mostly they are different types of anti-cellulite underwear. Seamless underwear, especially tops and bottoms, leggings, shorts, etc. are offered by many producers [5]. According to the producer's declaration, such a kind of underwear improves blood circulation and removes liquid from the body. Apart from the standard assortment of anti-cellulite underwear, there are also advanced products with additional pro-health features. The advanced anti-cellulite products contain special fibres or yarns, such as microfibres and silver and milk fibres, ensuring a natural bacteriostatic function.

Anti-cellulite underwear, especially with long legs and knee-length pants (***Figure 1***), have some significant disadvantages, taking into consideration current fashion trends and utility comfort. Especially they cannot be worn with a mini-skirt and dress. They are also inconvenient in the summer time due to the thermal discomfort.

Taking the above into consideration, it seems to be reasonable to elaborate anti-cellulite clothing goods (top/upper clothing) instead of anti-cellulite underwear. In 2004, the Miss Sixty clothing company introduced a range of jeans, trousers and skirts of anti-cellulite features. The anti-cellulite jeans contain Skintex, a serum made up of retinol and chitosan [6]. Anti-cellulite jeans by Miss Sixty can be considered as the most interesting anti-cellulite solution present on the market. Friction between denim and skin triggers the release of Skintex from microcapsules in the fabric. 40 percent of the active substances are absorbed after 48 hours. The anti-cellulite effectiveness is not durable, although the producer declares that the clothing remains effective even after 30 washings [6].

The Turbo Cell garment is another example of an anti-cellulite product present on the market [5, 6]. Turbo Cell is made with a special patented 3-layer fabric. The 1st external layer is made of stretch fabric that contains and shapes the body by working against the movements of the body. This layer also develops an even pressure, thus implementing the active phase of constant micro-massage. The 2nd middle layer of the natural latex increases the body temperature and activates blood circulation. The 3rd internal layer is made of cotton, which comes in contact with the skin, ensuring maximum tolerance for all types of skin. The specially designed weave enhances the micro-massage action. The thermal effect together with the constant micro-massage developed by the special Turbo Cell fabric effectively reduces the accumulation of localised fat as well as eliminates and fights the formation of cellulite [6]. The Turbo Cell garment has some disadvantages. In order to achieve anti-cellulite results, it should be worn at least for eight weeks and every day for 8 hours, which is practically impossible for the average woman, as it is too thick to be used during normal daily activity, home or professional, especially in the spring – autumn season. Turbo Cell garments must be hand washed at 40 °C and must not be ironed or dried near sources of heat. Taking into consideration the thickness of Turbo Cell clothing, the recommended way of its maintenance is extremely inconvenient.

At the Textile Research Institute (Lodz, Poland) innovative woven fabrics for anti-cellulite clothing were designed [5, 7]. The seersucker woven fabric developed ensures the mechanical micro-massage and stimulation of blood circulation due to the convex – concave structure and special surface properties of the fabric. The anti-cellulite efficiency of the fabrics designed was confirmed by means of an infrared camera.

Figure 1. *Examples of anticellulite pants; [https://e-medicalbroker.com].*

Experimental

The aim of the work presented was to design and investigate seersucker woven fabrics which can be used in anti-cellulite clothing, for instance anti-cellulite trousers. The design assumptions were the following:

- the fabrics should have a three-dimensional structure and rough textured surface,
- the bending stiffness and thermal resistance of the fabrics should be significantly higher than those of standard two-dimensional fabrics,
- additional pro-health properties (antibacterial, hygienic) of the fabrics designed can be achieved by introducing special fibres or yarns in the weft.

Materials and methods

Within the framework of the work presented, 4 variants of seersucker woven fabrics were designed. The fabrics were characterised by the seersucker effect in both the warp and weft directions. All fabric variants were manufactured on the basis of the same warps, made of 20 tex x 2 cotton yarn. The typical seersucker effect in the warp direction was achieved by an appropriate combination of warp yarns: basic and puckering of different tension while weaving. In the weft direction the seersucker effect was obtained thanks to the application of 37 tex PU 57/PES 33 elastomeric yarn alternately with non-elastomeric weft yarns in an appropriate configuration. The following non-elastomeric weft yarns were applied in the weft:

- 12 tex x 2 PES88/dri*release* SeeCell Active 12,
- 18.5 tex x 2 SPF (soybean protein fibres),
- 15.6 tex x 2 PES 156/94/2 ThermoCool Fresh,
- 235/34 dtex x 2 PA 6.6 94/ 34x2 Shieldex® 6.
- 20 tex x 2 cotton.

Dri*release*® is a blend of specific hydrophobic synthetic fibres with hydrophilic fibres of an optimised share of components. In the yarn applied, the profiled PES fibres were blended with SeeCell active fibres with antimicrobial and skin care features. The specific combination of hydrophobic and hydrophilic fibres allows to pull moisture away from the skin and fast drying. Soybean protein fibres are man-made renewable fibres made of botanic proteins from soybean cake. Soybean fibres have good biocompatibility with the human organism. Their protein contains 16 polar amino-acids necessary for the human-body [8, 9]. Thermocool™ fibre by Invista is designed to work with the body's natural thermal capabilities through smart fibre cross-sections: duo-regulation™ adapts to the wearer's needs.

Thermocool™ fibre is made with a unique combination of different engineered fibre cross-sections: hollow and profiled. It rapidly evaporates moisture thanks to its unique fibre mix. The fibres are designed to provide an added evaporative surface with outstanding moisture transport, which also allows enhanced air circulation, focusing energy on the evaporation process. Thermocool Fresh creates a permanent effect thanks to the active ingredients built into the fibre [9]. Shieldex is a silver plated polyamide yarn of anti-static and anti-bacterial properties.

All weft yarns mentioned above were applied in order to improve the functionality of the seersucker woven fabrics designed, especially to provide thermo-physiological comfort and antibacterial properties.

The fabrics investigated are presented in ***Figure 2***.

The basic structural parameters of the fabrics investigated are presented in ***Table 1***.

The fabrics were measured in the range of their basic structural and mechanical parameters. Additionally, due to the application in anti-cellulite clothing predicted, the measurement was performed in the range of properties important from the point of view of anti-cellulite effec-

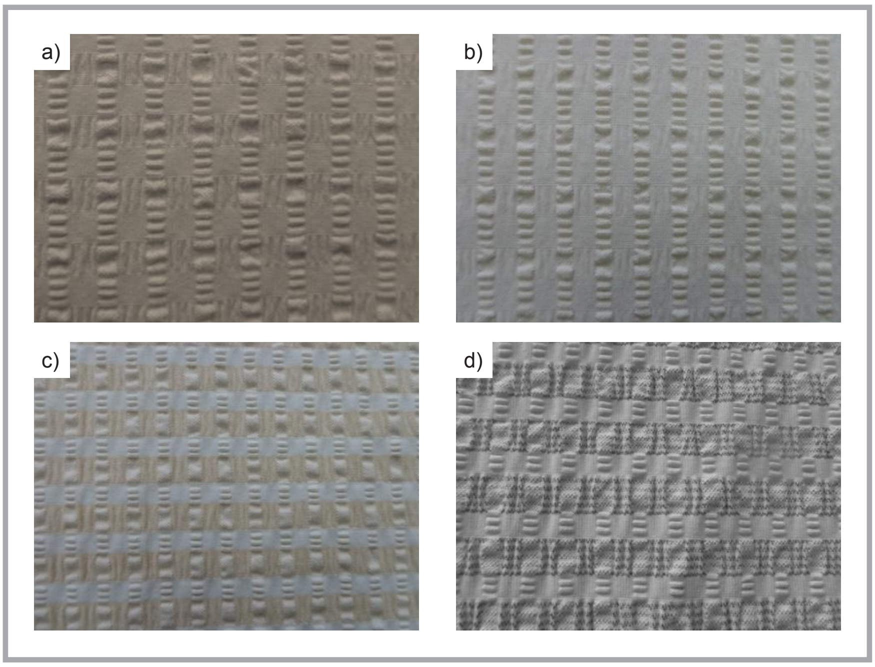

Figure 2. *Pictures of seersucker woven fabrics investigated: a) sample 1, b) sample 3, c) sample 2, d) sample 4.*

Table 1. *Characteristics of the seersucker woven fabrics manufactured.*

Parameter	Value			
	Sample 1	Sample 2	Sample 3	Sample 4
Warp I	20 tex x 2 CO	20 tex x 2 CO	20 tex x 2 CO	20 tex x 2 CO
Warp II	20 tex x 2 CO	20 tex x 2 CO	20 tex x 2 CO	20 tex x 2 CO
Weft I	37 tex PU57/ PES43 (elastomeric)	37 tex PU57/ PES43 (elastomeric)	37 tex PU57/ PES43 (elastomeric)	37 tex PU57/ PES43 (elastomeric)
Weft II	12 tex x 2 dri*release (PES* 88/ SeeCell Active12)	18,5 tex x 2 SPF	15.6 tex x 2 PES 156/94/2 ThermoCool Fresh	235/34 dtex x 2 PA 6.6 94/Silver 6
Weft III	–	–	–	20 tex x 2 CO
Weave – warp I	plain			
Weave – warp II	weft rep 2/2			

Table 2. *Parameters and basic properties of the seersucker woven fabrics investigated.*

Parameter	Unit	Value			
		Sample 1	Sample 2	Sample 3	Sample 4
Mass per square meter	gm^{-2}	357 (2.5)	373 (3.0)	332 (4.1)	365 (2.0)
Warp density	dm^{-1}	351 (0.18)	344 (0.15)	359 (0.18)	342 (0.34)
Weft density	dm^{-1}	286 (0.09)	273 (0.11)	264 (0.14)	240 (0.36)
Warp I take up	%	8.03	6.06	6.73	8.31
Warp II take up	%	75.5	74.3	64.1	72.7
Weft I take up	%	91.6	96.1	95.9	91.1
Weft II take up	%	39.8	36.5	44.7	43.2
Weft III take up	%	–	–	–	42.2
Thickness	mm	1.89 (0.05)	1.87 (0.03)	1.69 (0.02)	1.90 (2.50)
Breaking force – warp	N	519.0 (29.36)	540.0 (28.65)	533.0 (30.55)	503.0 (28.67)
Breaking force – weft	N	347.4 (13.10)	308.5 (18.41)	363.4 (21.45)	574.0 (14.28)
Elongation at break – warp	%	13.72 (2.61)	12.31 (0.36)	14.14 (0.30)	13.98 (0.28)
Elongation at break – weft	%	56.1 (0.98)	48.11 (0.88)	68.1 (2.04)	66.1 (2.70)

tiveness: thermal resistance, air permeability, surface properties, bending stiffness and antibacterial properties.

Measurements of the basic structural properties were made according to the standardised procedures. Measurement of the breaking force was performed according to PN EN ISO 13934-1: 2013 – 7 [10]. For each sample 10 repetitions were performed in both the warp and weft directions, and next the average value was calculated from 10 results.

The thermal resistance of the fabrics was measured using an Alambeta device (Sensora, Czech Republic) [11-13]. Measurement was made according to the Internal Standard of the Technical University of Liberec [14]. For each sample 10 repetitions of measurement were performed, and next the arithmetic mean was calculated as a final result.

In order to measure the bending stiffness, the Peirce method with a cantilever was applied according to Standard PN-P-04631:1973 [15]. For each fabric direction 5 repetitions of measurement were made in the warp and weft directions. The total bending stiffness is calculated from the bending stiffness in the warp and weft direction according to ***Equation (1)***:

$$B_{Tot} = \sqrt{B_{warp} \times B_{weft}} \qquad (1)$$

where:
B_{Tot} – total bending stiffness,
B_{warp} – bending stiffness in warp direction,
B_{weft} – bending stiffness in weft direction.

The air permeability of the seersucker fabric was measured using a standardised method (PN-EN ISO 9237:1998) [16].

Fabric friction was measured using an inclined plane, where 3 repetitions of the measurement were performed in both fabric directions. Antibacterial properties of the fabrics were analysed according to the AATCC Test Method 100 – 1998 [17].

Results and discussion

Results of the measurements are presented in ***Tables 2*** and ***3***, in which the values of standard deviation of the results are presented in brackets.

Table 2 presents the basic structural and mechanical properties of the seersucker woven fabrics investigated.

On the basis of the results obtained, it was stated that the fabric variants elaborated differ from each other in the range of their structural parameters, which results from the fact that different kinds of yarns were applied in the weft. The weft yarns in particular fabric variants have a different linear density and diameter of the cross-section. Due to this fact it was necessary to apply different numbers of picks in order to obtain a correct, stable seersucker effect. Although the fabrics were made of the same set of warps on the same loom, the number of ends is also different, resulting from the different weft yarns and their properties, which influenced the fabrics' relaxation in the finishing process.

The take up of warp II is several times higher than that of warp I, which is a typical relationship for seersucker fabrics. Due to its very high take up, warp II gives a puckering effect and creates a seersucker effect.

The mechanical properties of the seersucker fabrics investigated are different. However, the breaking force and elongation at break are at a comparable level.

The functional properties, i.e. those important from the point of view of the anti-cellulite effectiveness of the fabrics: bending stiffness, surface friction and thermal resistance, are presented in ***Table 3***.

The lowest thermal resistance was noted for sample No. 3, which results from the lowest thickness of the fabric (***Table 2***). The highest thermal resistance was noted for fabric No. 2 with SPF in the weft, and next for fabric No. 4. Generally the thermal resistance of all fabric variants elaborated is significantly higher than that of typical woven fabrics of basic or derivative weaves. Due to this fact it was concluded that one of the aims of the investigation was achieved. The fabrics applied in anti-cellulite trousers should provide a thermal effect, which is important in anti-cellulite treatment.

The bending stiffness and surface friction are also very important from the point of view of the micro-massaging effect during usage of trousers made of the fabrics elaborated. The bending stiffness of seersucker fabrics is different in the warp and weft directions. Generally much higher stiffness was noted in the warp direction than in the weft .

Table 3. *Functional properties of the seersucker woven fabrics investigated.*

Parameter	Unit	Value			
		Sample 1	Sample 2	Sample 3	Sample 4
Thermal resistance	W^{-1} Km^2 10^{-3}	46.85 (1.52)	49.52 (2.66)	44.63 (1.92)	47.99 (2.21)
Air permeability	mm s^{-1}	137.3 (6.2)	90.6 (7.1)	86.5 (6.5)	176.7 (6.8)
Bending stiffness in warp direction	mNm	0.161	0.196	0.148	0.207
Bending stiffness in weft direction	mNm	0.073	0.070	0.050	0.074
Total bending stiffness	mNm	0.108	0.117	0.086	0.124
Static friction coefficient in warp direction	–	0.985 (0.128)	0.860 (0.044)	0.899 (0.261)	0.972 (0.083)
Static friction coefficient in weft direction	–	1.428 (0.051)	1.206 (0.131)	1.366 (0.096)	1.201 (0.168)
Kinetic friction coefficient in warp direction	–	0.678 (0.022)	0.609 (0.021)	0.522 (0.078)	0.699 (0.059)
Kinetic friction coefficient in warp direction	–	0.753 (0.033)	0.743 (0.081)	0.764 (0.011)	0.788 (0.069)
Average kinetic friction coefficient	–	0.7145	0.6727	0.6315	0.7422

The highest total bending stiffness occurred for sample No. 4, and next for sample No. 2. The lowest bending stiffness was noted for sample No. 3.

From the point of view of micro-massaging activity, the surface properties are very important. All fabric variants are characterised by a rough surface, which could be stated in an organoleptic way. However, the surface roughness of the fabrics investigated has not been measured until now. Measurement of the roughness is predicted in the further step of the investigations. All fabrics were measured in the range of friction properties. Among the different friction parameters (***Table 3***), the kinetic friction coefficient seems to be more important than the static friction coefficient. In the warp direction the highest kinetic friction coefficient was noted for samples No. 4 and No. 1, and in the weft direction for samples No. 4 and No. 3.

The average kinetic friction coefficient expresses the kinetic friction coefficients in the warp and weft directions, calculated according to the following ***Equation (2)***:

$$\mu_{kave} = \sqrt{\mu_{kwarp} \times \mu_{kweft}} \qquad (2)$$

where:
μ_{kave} – average kinetic friction coefficient,
μ_{kwarp} – kinetic friction coefficient in warp direction,
μ_{kweft} – kinetic friction coefficient in weft direction.

The highest average kinetic coefficient occurs for fabrics No. 4 and 1, due to which it is justified to conclude that samples No. 4 and no. 1 have the best ability to massage during usage of trousers made of them.

Air permeability is one of the most important comfort-related properties of fabrics. It determines the resistance of fabrics (woven, knitted and nonwoven) to the passage of air [18, 19]. The air permeability of clothing directly influences the gas exchange between a human being and surroundings and, in the same way, the physiological comfort of the clothing user. Due to this fact air permeability is considered as one of the crucial comfort–related properties of clothing.

The air permeability of the seersucker woven fabrics investigated is in the range from 86.5 to 176.7 mms^{-1}. The highest air permeability occurred for sample No. 4, containing silver weft yarn, and next sample No. 1. Higher air permeability is better from the point of view of body ventilation and physiological comfort. Taking this into consideration, samples No. 4 and No. 1 are better than samples No. 2 and No. 3.

The physiological comfort of clothing usage also depends on the ability of fabrics for moisture transport. In this aspect two features are crucial: water-vapour permeability and the transport of liquid. The last feature can be assessed using a Moisture Management Tester. Until now the seersucker fabrics investigated have not be assessed in this aspect, which will be done in the next step of the investigations.

The investigation performed showed that the fabrics designed differ from each other in the aspect of their basic, mechanical and functional properties, resulting from the application of different weft yarns.

Unfortunately the antibacterial tests did not confirm the antibacterial properties of the seersucker fabrics designed. Probably the share of antibacterial yarns (dri*release*® SeeCellActiv, ThermoCool Fresh and Shieldex®) in samples No.1, No. 3 and No. 4 was too low, which should be taken into consideration in further works aimed at the elaboration of textile materials for anti-cellulite clothing.

The differences noted in the mechanical and functional properties of the fabrics investigated results mostly from the various properties of the weft yarns, being of different linear density and made from various raw materials. From the point of view of the predicted application as fabrics ensuring micro-massage, the higher bending stiffness, roughness and kinetic friction mean better ability for massaging action. Thermal resistance is also very important. The higher the thermal resistance is, the better the performance of the fabric as an anticellulite material, due to the thermal effect necessary in anticellulite treatment. From the point of view of physiological comfort, higher air permeability means better body ventilation. Taking the above into account at the moment, sample No. 4 was assessed as the best among all fabrics investigated.

However, the work is continuing. In the further step of investigations the surface roughness will be measured in order to select the best fabric from the point of view of massaging action. Comfort-related properties of the fabrics, especially water-vapour permeability and overall moisture management, will be assessed as well. Next anti-cellulite trousers will be manufactured from the fabrics designed. The effectiveness of the anti-cellulite action of the trousers will be assessed in utility trials

Conclusions

In the work presented, seersucker woven fabrics for anti-cellulite clothing were designed and manufactured. The fabrics were measured in the range of their structural, mechanical, comfort-related and functional properties.

The results obtained confirmed that the thermal resistance of the elaborated fabrics is much higher than that of typical woven fabrics of basic and derivative weaves, commonly applied in daily-use clothing. At the same time, the seersucker fabrics designed are able to ensure a thermal effect during the usage of trousers made of them.

The fabrics are characterised by high bending stiffness and surface roughness. Both features are important from the point of view of the massaging action of trousers made of the fabrics developed. Surface friction is different depending on the fabric variant. The highest average kinetic friction coefficient occurred for fabric No. 4. This variant is also characterised by the highest bending stiffness and air permeability and second highest thermal resistance.

On the basis of the results obtained until now, sample No. 4 can be considered as the best variant from the point of view of anti-cellulite effectiveness. However, it is necessary to perform a measurement of the ability of fabrics for moisture transport and next utility trails.

The antibacterial tests did not confirm the antibacterial properties of the seersucker fabrics designed. Probably the share of antibacterial yarns (dri*release*® SeeCellActiv, ThermoCool Fresh and Shieldex®) in samples No. 1, No. 2 and No. 3 was too low, which should be taken under consideration in further works aimed at the elaboration of textile materials for anti-cellulite clothing.

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