(REFEREED RESEARCH)

ANALYSIS OF KNITTED FOOTWEAR LININGS FOR DIABETIC PATIENTS

DİYABET HASTALARININ KULLANACAĞI ÖRME AYAKKABI ASTARLARININ İNCELENMESİ

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ABSTRACT

Diabetes and arthritis are the most common chronic diseases in the world. Diabetes can damage many parts of the body, leading to severe cardiac conditions, strokes, visual impairment, impotence, renal and podiatric problems. Part of the problem is the loss of feeling in patients' feet and giving way to blisters or injuries resulting in deep sores (ulcers). Selection of adequate footwear plays an important role for diabetic and arthritis patients. The aim of this study is to investigate the effects of fabric structure and yarn type on the performance and physical characteristics of the functional knitted fabrics that will be appropriate for footwear linings of patients with locomotor disorders caused by diabetes and arthritis. In order to determine related footwear standards, tensile strength, tensile elongation, water vapour permeability properties and physical parameters were measured and evaluated for the selection of the fabrics with optimum parameters.

Keywords: Raw material, fabric construction, knitted fabrics, footwear performance tests

ÖZET

Diyabet ve artrit dünyada en sık görülen kronik hastalıklardır. Diyabet, kalp krizi, inme, ayak problemleri, iktidarsızlık, böbrek ve göz gibi vücudun birçok uzvunda hasara neden olabilen bir hastalıktır. Diyabetli kişilerin genellikle ayakları ile sorunları vardır. Sorunun bir bölümünü diyabetli kişilerin ayaklarında his kaybı oluşmasından ötürü, su toplama veya yara oluşumu geç algılamaları oluşturmaktadır ve yaraların tedavi edilmemesi durumunda ülser ile sonuçlanabilmektedir. Uygun ayakkabının seçimi diyabet ve artrit hastaları için büyük önem taşımaktadır. Bu çalışmada, diyabet ve artritten kaynaklanan lokomotor bozukluklara sahip hastaların kullanacağı ayakkabı astarları için uygun fonksiyonel örme kumaşların performans ve fiziksel özelliklerine kumaş yapısı ve iplik tipinin etkisinin incelenmesi amaçlanmaktadır. İlgili ayakkabı standardına uygun olarak optimum parametrelere sahip kumaşların seçimi için, kumaşların kopma mukavemeti, kopma uzaması, su buharı geçirgenliği özellikleri ve fiziksel parametreleri ölçülmüş ve değerlendirilmiştir.

Anahtar Kelimeler: Hammadde, kumaş konstrüksiyonu, örme kumaşlar, ayakkabı performans testleri

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1. INTRODUCTION

Diabetes and arthritis are the most common chronic diseases in the world. Diabetes is a condition in which the body is unable to automatically regulate blood glucose levels, resulting in too much glucose (a type of sugar) in the blood. Diabetes can damage many parts of the body, resulting in severe cardiac conditions, strokes, podiatric problems, impotence, renal and visual impairment [1]. The term arthritis literally means "joint inflammation," but it is generally used to refer to a family of more than 100 different conditions that affect the joints and may also affect muscles and other tissues [2]. The International Diabetes Federation (IDF) estimates that 246 million people are suffering from this disease worldwide, increasing to 380 million over the next 20 years. The greatest incidence rate is in Eastern and Mediterranean Europe, where 9% of adults have diabetes, followed by North America with 8%. However, 80% of these cases are seen in developing countries [3]. Approximately 15% of diabetics develop mellitus on the feet level due to low resistance to infections, affecting the elderly the most [4].

Studies on the factors that influence diabetic footwear conducted by research teams around the world have shown that it significantly reduced the incidence of ulcerations on the bodily segments of patients examined [5]. The arthritic foot requires special attention, due to the way it influences the equilibrium and walking stability, affecting the elderly the most.

People with diabetes often have trouble with their feet. Part of the problem is the loss of feeling in their feet and having a blister or sore resulting in deeper sores (ulcers). If these ulcers become infected, the patients may have to go to the hospital or, in very serious cases, have a foot amputated (removed). Therefore, selection of adequate footwear plays an important role for diabetic patients.

Inadequate footwear represents a factor which favours structural and functional abnormalities that induce locomotor disorders such as hummer toe. Studies proved that feet amputation in diabetics was preceded by minor traumatisms, many of which were caused by inadequate footwear. The problems of diabetic feet, the epidemiological dynamics of ulcerations mellitus and amputations in diabetic patients continue to be a source of concern. There are only few studies on this matter, comparing it with other complications of diabetes. There are major differences in reporting prevalence and amputation incidence rates whilst these are relatively easy to assess [6]. The same reference shows that “published data suggest a prevalence of diabetic feet varying between 5 and 80%.”

Considering feet sensibility on the tegumental level, caused by diseases that induce locomotor disabilities, special materials must be selected based on their healthy and user-friendly characteristics and also on comfort parameters like air permeability, water vapor permeability, thermal insulation, elasticity and softness.

The interaction between foot and footwear is achieved by linings; it is obvious that main functions are to increase the comfort and durability of the footwear, softness or protection where needed [7, 8]. During wearing, linings must protect the foot skin against the direct contact of the foot with the semi-rigid footwear components such as a stiffener and a toe cap. A lining must prevent an upper from distortion and ensure the stability of the spatial form and, hence, maintain the products’ aesthetic look over time. To assure feet comfort, the footwear lining material should have basic characteristics such as: good hygienic properties (absorption capacity, air and water vapour permeability, capacity to remove static electricity, etc.), high resistance to stress and strain, good resistance to perspiration, and good dyeing resistance [9].

Some studies have been carried out on the mechanical characteristics of knitted fabrics. Heide et al. reported research results showing the possibilities of using permanently effective antimicrobial yarns in fabrics used for medical footwear insoles. The antimicrobial knitted fabrics could be a very useful application for footwear lining, moreover, a large demand for such commercial products has been reported recently [10]. Jeon et al. examined the mechanical properties and abrasion behaviour of warp knitted fabrics for footwear. They noted that the weight and thickness of the fabric, the frictional coefficient, and also the surface roughness were influenced by the abrasion conditions. The frictional coefficient of fabric surface increased at the beginning of abrasion and decreased as abrasion cycles increased. The weight and thickness of the fabric linearly decreased with the increase of abrasion cycles. The surface roughness and the compressional resilience decreased as abrasion cycles increased [11]. Blaga et al. reported the influence of fibers’ blend ratio between Cotton and Soybean/SeaCell on the wear behaviour of the knitted fabrics for footwear linings, among such properties as fabric extensibility, initial elastic modulus and dyeing behaviour [12]. Blaga et al. examined the effect of yarn type, fabric tightness and finishing on the behaviour of knitted fabrics for footwear linings among such properties as fabric extensibility, pilling, friction properties, initial elastic modulus [9]. Blaga et al. [13] and Marmaralı et al. [14] analysed the physical and comfort properties of single jersey fabrics made of functional yarns like Coolpass, Coolmax, Outlast and Dri-Release, for footwear linings. They have demonstrated the utility of these yarns for linings of orthopaedics footwear, where comfort properties are mostly required. Ertekin et al. [15] determined functional knitted fabrics produced with different yarns and structures that would be appropriate for footwear linings. Blaga et al. [16] investigated the physical and thermal comfort attributes of flat knitted spacer and interlock fabrics designed for shoe linings. They produced interlock and flat knitted spacer fabrics by using Cotton, Cotton/Bamboo, Cotton/Type A blended yarn and Cotton/Type B blended yarn and measured fabric extensibility, friction coefficient, water vapour permeability, air permeability and thermal comfort properties (thermal conductivity, thermal resistance and thermal absorptivity) of the fabrics. They stated that, according to the extensibility and friction coefficient values of the samples, all spacer fabrics and interlock fabrics produced with Cotton/Type A and Cotton/Bamboo blended yarn were appropriate fabrics for shoe linings.

The aim of this study is to investigate the effects of material composition and fabric construction on required performance characteristics. Additionally, the possibility of using functional knitted fabrics developed in this study to be used for footwear linings of patients with locomotor disorders caused by diabetes and arthritis has been investigated as well.

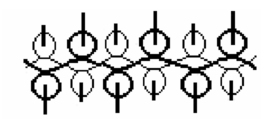
2. EXPERIMENTAL

This study aims to determine functional knitted fabrics designed for footwear linings of patients with locomotor disorders caused by diabetes and arthritis. For this purpose, cotton, bamboo, silver, “Type A” yarn, “Type B” yarn and “Type C” yarns were used in the yarn production and the cotton yarns and their blends were produced at yarn counts of 20/1 and 27/1 Nm. “Type A” yarn was produced based on a new and novel process: the polyester melt spun bicomponent process utilizing a PCM core with standard polyester as the sheath. This process delivered a level of temperature managing the fiber without compromising standard polyester fiber downstream processing, dyeing and finishing properties [17]. “Type B” yarn was the purest cellulose fibre obtained from renewable resource. The fibres retained the wood's natural properties. The main differences in this yarn compared to other cellulose fibres were its softness, absorption capacity, ability to release dampness (as a yarn or fabric), deodorant properties, and adsorption characteristics (due to its morphology) [18]. “Type C” yarn was a cellulose fibre which was produced by the so-called Lyocell process using cellulose and seaweed. The Lyocell process has established itself as an environmentally-friendly, economically viable, product-enhancing and highly flexible alternative for the manufacture of man-made cellulose fibres [19]. The list of the yarns is given in Table 1.

Table 1. Yarns used in this study

Yarn count	Blend ratio(%)	Material	Fabric production
27/1 Nm	100	Cotton (Ring)	For the production of circular knitted interlock fabrics
	100	Cotton (Compact Ring)	
	100	Bamboo	
	70/30	Bamboo/Cotton (OE)	
	60/40	Bamboo/Cotton (OE)	
	3/97	Silver/Cotton (OE)	
	6/94	Silver/Cotton (OE)	
20/1 Nm	100	Cotton (Ring)	For the production of flat knitted interlock and spacer fabrics
	100	Cotton (OE)	
	100	"Type A"	
	60/40	"Type B"/Cotton (Ring)	
	50/50	Bamboo/Cotton (Ring)	
	20/80	"Type C"/Cotton (OE)	
	3/97	Silver/Cotton (OE)	
	6/94	Silver/Cotton (OE)	

Table 2. The fabrics used in this study

Fabric structure	Nr.	Type of yarn	Tightness
Circular knitted interlock fabric 	1	100% Cotton (Ring)	Tight (3.2)
	2		Medium (5.0)
	3		Loose (5.2)
	4	100% Cotton (Compact Ring)	Tight (3.2)
	5		Medium (5.0)
	6		Loose (5.2)
	7	100% Bamboo	Tight (3.2)
	8		Medium (5.0)
	9		Loose (5.2)
	10	70/30 % Bamboo/Cotton	Tight (3.2)
	11		Medium (5.0)
	12		Loose (5.2)
	13	60/40 % Bamboo/Cotton	Tight (3.2)
	14		Medium (5.0)
	15		Loose (5.2)
	16	3/97% Silver/Cotton	Medium (5.0)
	17	6/94% Silver/Cotton	Medium (5.0)

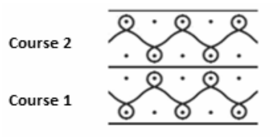
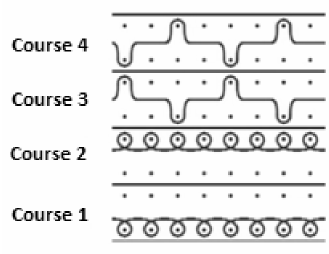
Fabric structure	Nr.	Fabric codes		Type of yarn	
		Face	Back	Face	Back
Flat knitted interlock fabric 	1	Co(OE)		100% Cotton (Open- End)	
	2	Co(RG)		100 % Cotton (Ring)	
	3	"Type A"		100 % "Type A"	
	4	Co("Type B")		40/60% Cotton/"Type B"	
	5	Co("Type C")		80/20% Cotton/"Type C"®	
	6	Co(BA)		50/50 % Cotton/Bamboo	
	7	Ag/Co (%6)		94/6% Cotton/Silver	
	8	Ag/Co (%3)		97/3% Cotton/Silver	
Flat knitted spacer fabric 	9	Co(OE)		100% Cotton (Open- End)	
	10	Co(RG)		100 % Cotton (Ring)	
	11	"Type A"		100 % "Type A"	
	12	Co("Type B")		40/60% Cotton/"Type B"	
	13	Co("Type C")		80/20% Cotton/"Type C"	
	14	Co(BA)		50/50 % Cotton/Bamboo	
	15	Ag/Co (%6)		94/6% Cotton/Silver	
	16	Ag/Co (%3)		97/3% Cotton/Silver	
	17	Co(OE)- "Type A"		100% Cotton (Open- End)	100 % "Type A"
	18	Co(OE)-Co("Type B")			40/60% Cotton/"Type B"
	19	Co(OE)-Co("Type C")			80/20% Cotton/"Type C"
	20	Co(OE)-Co(BA)			50/50 % Cotton/Bamboo
	21	Co(RG)-Co(OE)		100 % Cotton (Ring)	100% Cotton (Open- End)
	22	Co(RG)- "Type A"			100 % "Type A"
	23	Co(RG)-Co("Type B")			40/60% Cotton/"Type B"
	24	Co(RG)-Co("Type C")			80/20% Cotton/"Type C"
	25	Co(RG)-Co(BA)			50/50 % Cotton/Bamboo
	26	"Type A" -Co("Type C")		100 % "Type A"	80/20% Cotton/"Type C"
	27	"Type A" -Co(BA)			50/50 % Cotton/Bamboo
	28	Co("Type B")- "Type A"		40/60% Cotton/"Type B"	100 % "Type A"
	29	Co("Type B")-Co("Type C")			80/20% Cotton/"Type C"
	30	Co("Type B")-Co(BA)			50/50 % Cotton/Bamboo

Table 3. Measured parameters and related standards

Parameters	Related Standard	Measuring device
Courses/cm, Wales/cm	TS 250 EN 1049-2	Magnifying glass
Mass per unit area	TS 251	Scale
Thickness	TS 7128 EN ISO 5084	SDL Atlas M 034A digital thickness gauge
Fabric extensibility in wale and course directions	BS 4294	SDL Atlas Fryma Fabric Extensometer
Fabric friction coefficient	BS 3424	Shirley Fabric Friction Tester M264
Tensile strength, tensile elongation	ASTM D 2209	SATRA STM 466, 466F
Water vapour permeability	ASTM D 5052	SATRA, STM 175

The fabrics were produced:

- in different knitted structures (flat/circular knitted interlock and flat knitted spacer fabrics)
- in different tightness values (only for circular knitted interlock fabrics)
- by using different yarn combinations in face and back side of the fabric (only for flat knitted spacer fabrics)

The production of interlock fabrics was performed both circular and flat knitting machines. Circular knitted interlock fabrics were produced on a 18 gauge and 30” diameter Fouquet circular knitting machine in three different tightness values (3.2, 5.0, 5.2). An electronic flat knitting machine CMS 530 E 6.2 was used in the production of flat knitted interlock and spacer fabrics. For the production of the spacer fabric, polyamide with a count of 20/1 Nm was also used as a spacer yarn. 47 fabrics in total were knitted by using the yarns listed in Table 1. The details of the fabrics and their needle diagrams are given in Table 2. After the knitting process, the fabric samples were kept under the standard atmospheric conditions for relaxation.

Within the scope of this study, the tensile strength, tensile elongation, water vapour permeability, extensibility and friction coefficient tests were performed to analyse the required performance characteristics for footwear components as mentioned in ISO/TR 20882:2007. Furthermore, physical parameters including courses/cm, wales/cm, mass per unit area and thickness were also measured and taken into consideration while selecting the appropriate structures and materials for high performance footwear linings. The measured parameters and related standards are given in Table 3.

3. RESULTS AND DISCUSSION

The dimensional characteristics of the fabrics such as courses/cm (cpc), wales/cm (wpc), mass per unit area and thickness as well as the physical and footwear performance properties of the fabrics are presented in Table 4 and Table 5, respectively.

As illustrated in Table 4, the thickness of the samples varied from 1.24 mm to 1.51 mm for circular knitted interlock fabrics, 1.76-2.35 mm for flat knitted interlock fabrics and 2.54-3.22 mm for flat knitted spacer fabrics. When construction types were compared, the smallest thickness values were obtained from the circular knitted interlock fabrics. In case of spacer fabrics, spacer yarn forms the fabrics and forces the layers to be distanced, thus making their thickness values higher than the interlock ones. Due to the addition of monofilament yarn into the structure, spacer fabrics have higher mass per unit area values than interlock fabrics.

Fabric extensibility is defined as the capacity to reach the maximum value of elongation when subjected to forces below breaking point. In the case of footwear linings, this property is required for the upper part formability and 3D shaping. These materials also demand characteristics like soft-feel in wearing and flexibility to keep the possibility of friction at the lowest point [9]. It was confirmed that the testing direction (course-wise vs wale-wise) had a higher influence compared to the knitted structure and the type of yarn (Table 5). The results indicated that due to the direction of loop forming in weft knitting technique, the extensibility in course-wise has higher than in wale-wise. When stretching the fabric in course-wise, the yarn was redistributed and the loop shape reduced its wale spacing and increased its course spacing. On the contrary, when applying the force in wale-wise, the redistribution of the yarn was considerably smaller. For circular knitted interlock fabrics, looser fabrics were found to be the most extensible ones in both course and wale direction with respect to the other samples. 100% “Type A” fabric and fabrics containing silver yarns had higher extensibility values in both directions for flat knitted interlock fabrics. It was also observed that spacer fabrics were the most balanced fabric structures with closest extensibility values in both directions. It seems possible that these results were achieved due to the spacer yarn. The polyamide yarn provides dimensional stability to the fabric, forcing it to expand, almost with the same value in both directions. When construction types were compared, both circular and flat knitted interlock fabrics had higher extensibility values in course direction than spacer fabrics.

The frictional behaviour of textile structures is of considerable importance especially in footwear components. The friction coefficient of linings refers to the sliding resistance between leather and lining. In the upper part of the footwear, lining and leather are attached together. If the friction between leather and lining is too low, the linings begin to slide and wrinkles will occur on the surface of the linings and this will cause an uncomfortable feeling for the wearer. According to “ISO/TR 20882:2007, Footwear - Performance requirements for components for footwear – Lining and insocks”, the friction coefficient of the materials designed for shoe linings should be equal to or higher than 0.7 [15]. Figure 1 shows that, all circular knitted interlock fabrics and flat knitted spacer fabrics meet the requirements for footwear linings. Additionally, only Cotton/”Type C” flat knitted interlock fabric is the appropriate structure in terms of friction coefficient value.

Table 4. Dimensional characteristics of the fabrics

Fabric structure	Nr.	Type of yarn	Tightness	cpc	wpc	Mass per unit area (g/m²)	Thickness (mm)
Circular knitted interlock fabric	1	100% Co (Ring)	Tight	15.2	10.8	435.77	1.39
	2		Medium	11.2	10.8	396.93	1.47
	3		Loose	10.8	10.4	361.47	1.51
	4	100% Co (Compact Ring)	Tight	15.2	10.8	433.97	1.32
	5		Medium	11.2	10.8	384.67	1.40
	6		Loose	10.4	10.4	373.03	1.44
	7	100% BA	Tight	13.2	10.8	325.67	1.24
	8		Medium	10.8	10.8	286.50	1.28
	9		Loose	9.6	10.4	274.83	1.26
	10	70/30 % BA/Co	Tight	14	10.8	432.23	1.24
	11		Medium	11.2	10.8	401.80	1.33
	12		Loose	10.4	10.8	372.07	1.38
	13	60/40 % BA/Co	Tight	14.8	10.8	427.53	1.34
	14		Medium	11.2	10.8	376.53	1.36
	15		Loose	10.4	10.8	373.23	1.44
	16	3/97% Ag/Co	Medium	11.6	10.8	368.47	1.50
	17	6/94% Ag/Co	Medium	11.2	10.8	382.67	1.45
Flat knitted interlock fabric	1	Co(OE)	NP :8.6	9	7	348.00	1.76
	2	Co(RG)		10	7	407.00	1.94
	3	"Type A"		8	8	244.00	1.88
	4	Co("Type B")		8	8	226.00	1.84
	5	Co("Type C")		9	9	368.56	1.84
	6	Co(BA)		9	7	368.75	1.79
	7	Ag/Co (%6)		7	7	320.67	2.35
	8	Ag/Co (%3)		7	6	297.40	2.35
Flat knitted spacer fabric	9	Co(OE)	NP :10.5	10	6	500.27	2.54
	10	Co(RG)		10	6	557.37	2.61
	11	"Type A"		9	5	381.73	2.62
	12	Co("Type B")		10	5	397.13	2.52
	13	Co("Type C")		10	6	532.36	3.05
	14	Co(BA)		10	6	536.34	3.05
	15	Ag/Co (%6)		11	6	576.24	3.22
	16	Ag/Co (%3)		11	6	554.18	3.10
	17	Co(OE)- "Type A"		10	5	471.93	2.54
	18	Co(OE)-Co("Type B")		10	5	473.47	2.60
	19	Co(OE)-Co("Type C")		10	6	540.46	2.88
	20	Co(OE)-Co(BA)		10	6	519.63	2.88
	21	Co(RG)-Co(OE)		11	6	573.27	2.55
	22	Co(RG)- "Type A"		10	6	491.50	2.84
	23	Co(RG)-Co("Type B")		10	6	481.43	2.62
	24	Co(RG)-Co("Type C")		10	6	565.05	2.88
	25	Co(RG)-Co(BA)		10	6	571.39	2.91
	26	"Type A"-Co("Type C")		9	7	456.20	3.02
	27	"Type A"-Co(BA)		10	6	462.08	3.08
	28	Co("Type B")- "Type A"		10	5	385.53	2.64
	29	Co("Type B")-Co("Type C")		9	6	468.70	3.07
	30	Co("Type B")-Co(BA)		10	6	464.49	3.09

Table 5. Physical and footwear performance characteristics of the fabrics

	Nr.	Type of yarn	Tightness	Extensibility		Friction coefficient		Tensile strength (N/mm^2)	Tensile elongation (%)	Evaporated water content(g)
				Course	Wale	Course	Wale			
Circular knitted interlock fabric	1	100% Co (Ring)	Tight	56	22	0.85	0.79	8.90	93.51	0.990
	2		Medium	109	25	0.89	0.79	7.53	77.78	1.012
	3		Loose	130	28	0.86	0.76	7.34	77.19	0.915
	4		Tight	65	20	0.89	0.83	9.59	86.29	0.947
	5	100% Co (Compact Ring)	Medium	111	23	0.89	0.79	8.91	73.08	0.995
	6		Loose	148	25	0.83	0.74	6.20	71.36	0.943
	7		Tight	82	26	0.86	0.74	6.42	68.21	1.52
	8	100% BA	Medium	114	24	0.88	0.82	5.31	59.88	1.3975
	9		Loose	142	24	0.89	0.85	6.53	60.06	1.423
	10		Tight	64	19	0.89	0.71	9.09	74.79	0.995
	11	70/30 % BA/Co	Medium	119	25	0.86	0.75	6.28	70.42	1.183
	12		Loose	147	25	0.86	0.79	7.08	64.42	0.987
	13		Tight	53	27	0.94	0.85	6.42	83.72	0.992
	14	60/40 % BA/Co	Medium	107	26	0.79	0.72	6.29	70.12	1.006
	15		Loose	149	29	0.8	0.73	7.16	69.23	0.934
	16	3/97% Ag/Co	Medium	109	25	0.83	0.79	6.18	81.60	1.081
	17	6/94% Ag/Co	Medium	115	24	0.86	0.8	6.57	82.22	0.968
Flat knitted interlock fabric	1	Co(OE)	NP :8.6	65.60	37.6	0.86	0.42	5.21	112.71	1.239
	2	Co(RG)		69.60	39.2	0.89	0.44	6.00	114.85	1.036
	3	“Type A”		229.60	49.4	0.38	0.24	4.81	105.01	1.679
	4	Co(“Type B”)		149.60	49.4	0.38	0.26	3.21	87.46	1.750
	5	Co(“Type C”)		75.00	33.7	0.97	0.79	3.57	95.04	0.925
	6	Co(BA)		94.67	37.7	0.92	0.63	4.83	100.81	0.858
	7	Ag/Co (%6)		237	55.2	0.31	0.77	3.07	91.48	1.070
	8	Ag/Co (%3)		240.6	50.6	0.28	0.72	2.84	93.89	0.952
Flat knitted spacer fabric	9	Co(OE)	NP :10.5	48.40	36.8	1.03	0.91	2.599	104.895	0.988
	10	Co(RG)		42.80	22.8	0.91	0.98	3.432	134.347	0.844
	11	“Type A”		53.20	40.6	0.99	1	1.183	98.198	1.411
	12	Co(“Type B”)		51.40	40.4	0.91	0.95	1.332	103.665	1.455
	13	Co(“Type C”)		43.33	32.0	0.93	1	1.777	101.620	0.779
	14	Co(BA)		43.33	32.0	0.93	1	1.528	90.721	0.811
	15	Ag/Co (%6)		40.4	44.8	0.85	0.71	1.983	102.005	0.860
	16	Ag/Co (%3)		35.2	42	0.88	0.68	1.823	103.317	0.782
	17	Co(OE)- “Type A”		35.80	34.4	1.03	0.91	2.710	96.292	1.297
	18	Co(OE)-Co(“Type B”)		40.00	35.2	1.03	0.91	2.220	100.752	0.806
	19	Co(OE)-Co(“Type C”)		41.67	28.0	1.03	0.91	2.387	96.358	0.762
	20	Co(OE)-Co(BA)		27.33	30.3	1.03	0.91	2.644	96.690	0.747
	21	Co(RG)-Co(OE)		30.80	27.2	0.91	0.98	2.955	111.463	1.079
	22	Co(RG)- “Type A”		39.20	36.8	0.91	0.98	2.261	98.590	0.963
	23	Co(RG)-Co(“Type B”)		37.20	32.4	0.91	0.98	1.926	91.650	0.883
	24	Co(RG)-Co(“Type C”)		35.00	30.3	0.91	0.98	2.319	107.457	0.809
	25	Co(RG)-Co(BA)		42.00	30.0	0.91	0.98	2.493	97.257	0.794
	26	“Type A”-Co(“Type C”)		57.33	30.3	0.99	1	1.409	82.625	0.743
	27	“Type A”-Co(BA)		60.00	35.0	0.99	1	1.399	87.917	0.742
	28	Co(“Type B”)- “Type A”		43.40	40.0	0.91	0.95	1.269	86.017	1.041
	29	Co(“Type B”)-Co(“Type C”)		55.00	28.0	0.91	0.95	1.690	82.775	0.804
	30	Co(“Type B”)-Co(BA)		52.33	30.7	0.91	0.95	1.473	121.985	0.824

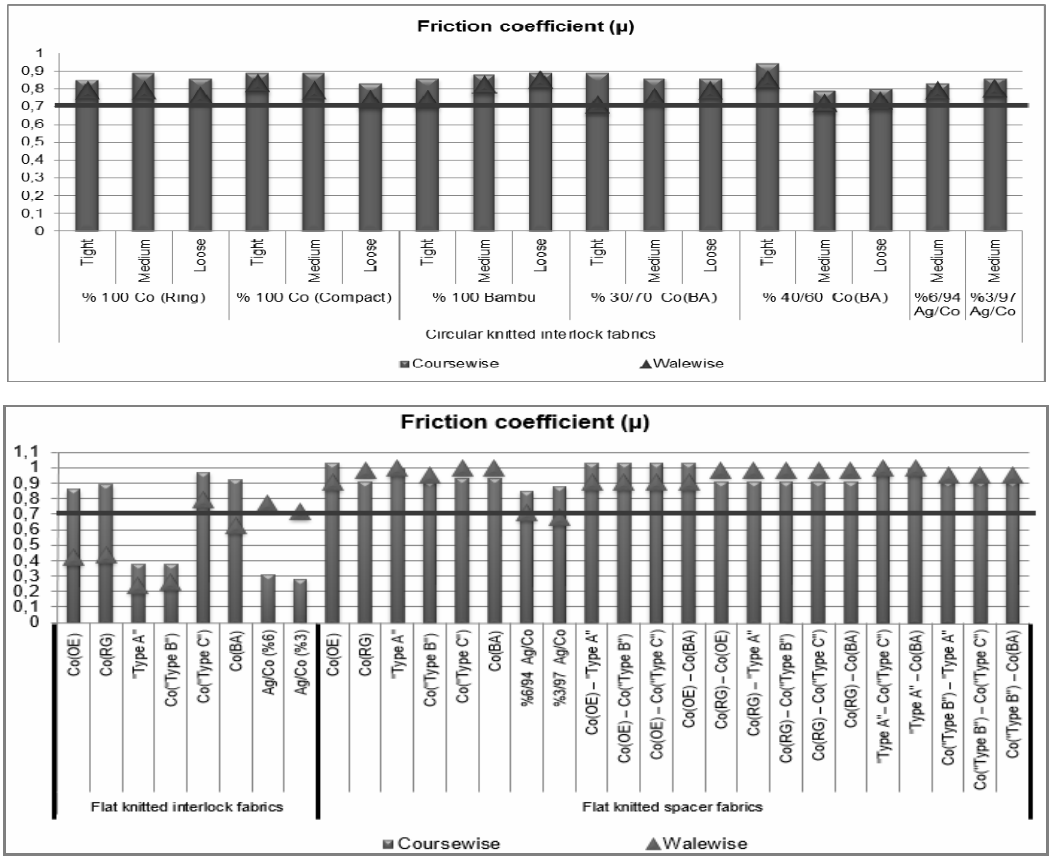


Figure 1. Friction coefficient values of the fabrics

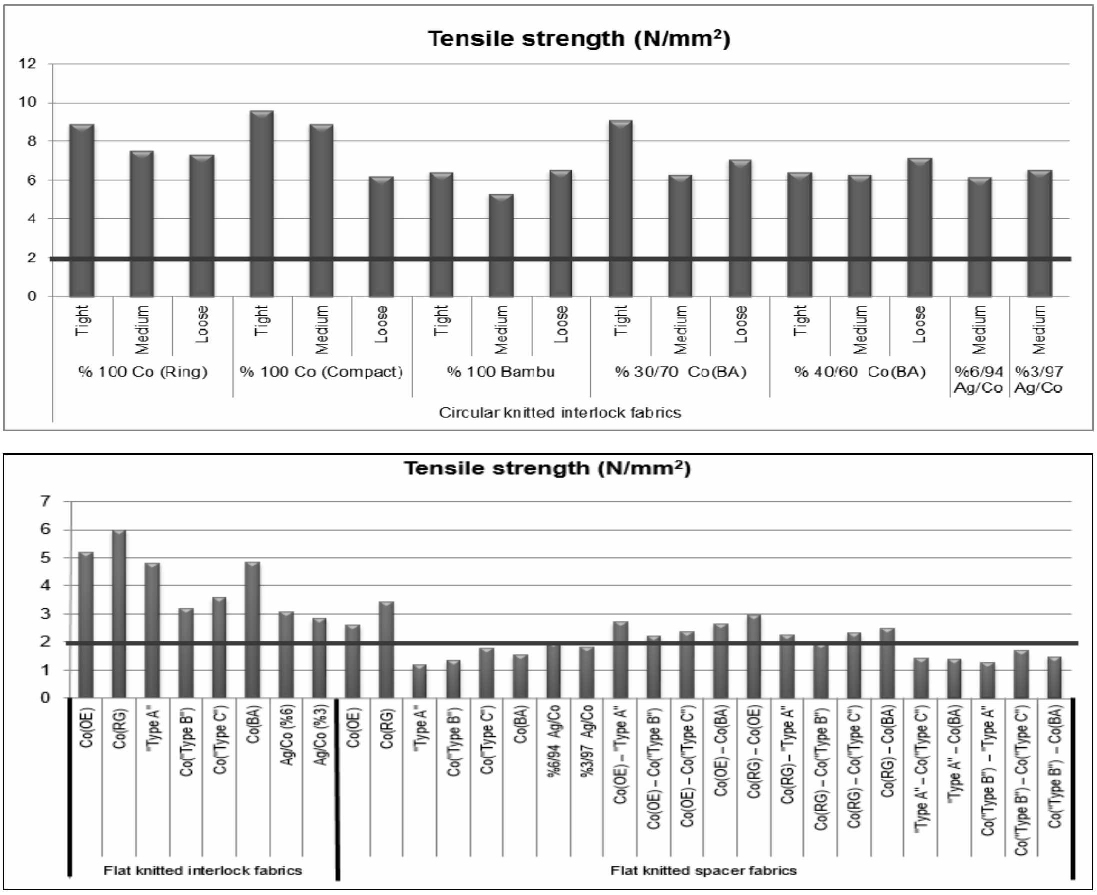


Figure 2. Tensile strength values of the fabrics

Tensile strength is the amount of stress that a material is able to withstand when pulled lengthwise before permanent deformation results. Tensile elongation, also known as elongation at break, is the ratio between changed length and initial length after breakage of the test specimen. It expresses the capability of a material to resist changes of shape without crack formation. According to the ISO/TR 20882:2007 standard, the tensile strength and tensile elongation of the materials designed for footwear linings should be equal to or higher than 2N/mm^2 and 80%, respectively. The results of tensile strength (Figure 2) indicated that, both flat and circular knitted interlock fabrics had higher tensile strength value than 2N/mm^2. 100% Cotton (Ring) and Cotton (OE) spacer fabrics and spacer fabrics with face side from Co(Ring) or Cotton (OE) and the back side from the other materials (Co("Type B"), "Type A", Co("Type C"), Co(BA)) meet the requirements of tensile strength for footwear linings.

As demonstrated in Figure 3, tight 100% Cotton fabrics, tight 40/60% Cotton/Bamboo fabric and fabrics containing silver yarn within circular knitted interlock fabrics and all flat knitted fabrics ensured the tensile elongation value of 80%.

For textile materials as well as for footwear linings, water vapour permeability is one of the most important comfort parameter. The water vapour permeability properties were measured under conditions that simulate the temperature inside the product while wearing shoes, according to the standard ASTM D 5052. The permeability of the material is determined by measuring the weight loss of the assembly at intervals throughout a four-hour period. Increasing the fabric weight in grams in total time indicates a higher permeability characteristic of the fabric. The highest permeability values were obtained from 100% bamboo circular knitted fabrics and flat knitted interlock/spacer fabrics containing Cotton/"Type B" or "Type A" yarns, as represented in Figure 4.

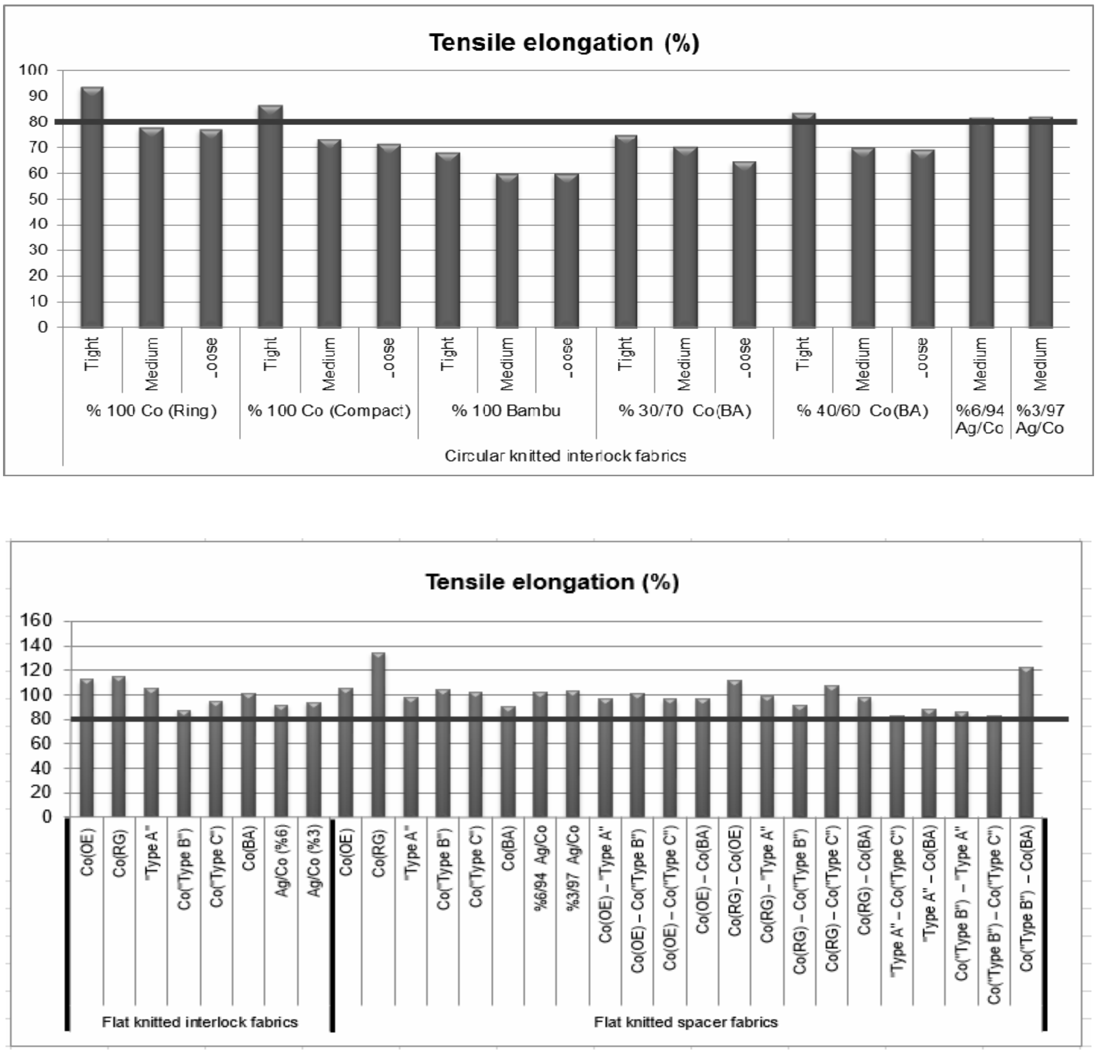


Figure 3. Tensile elongation values of the fabrics

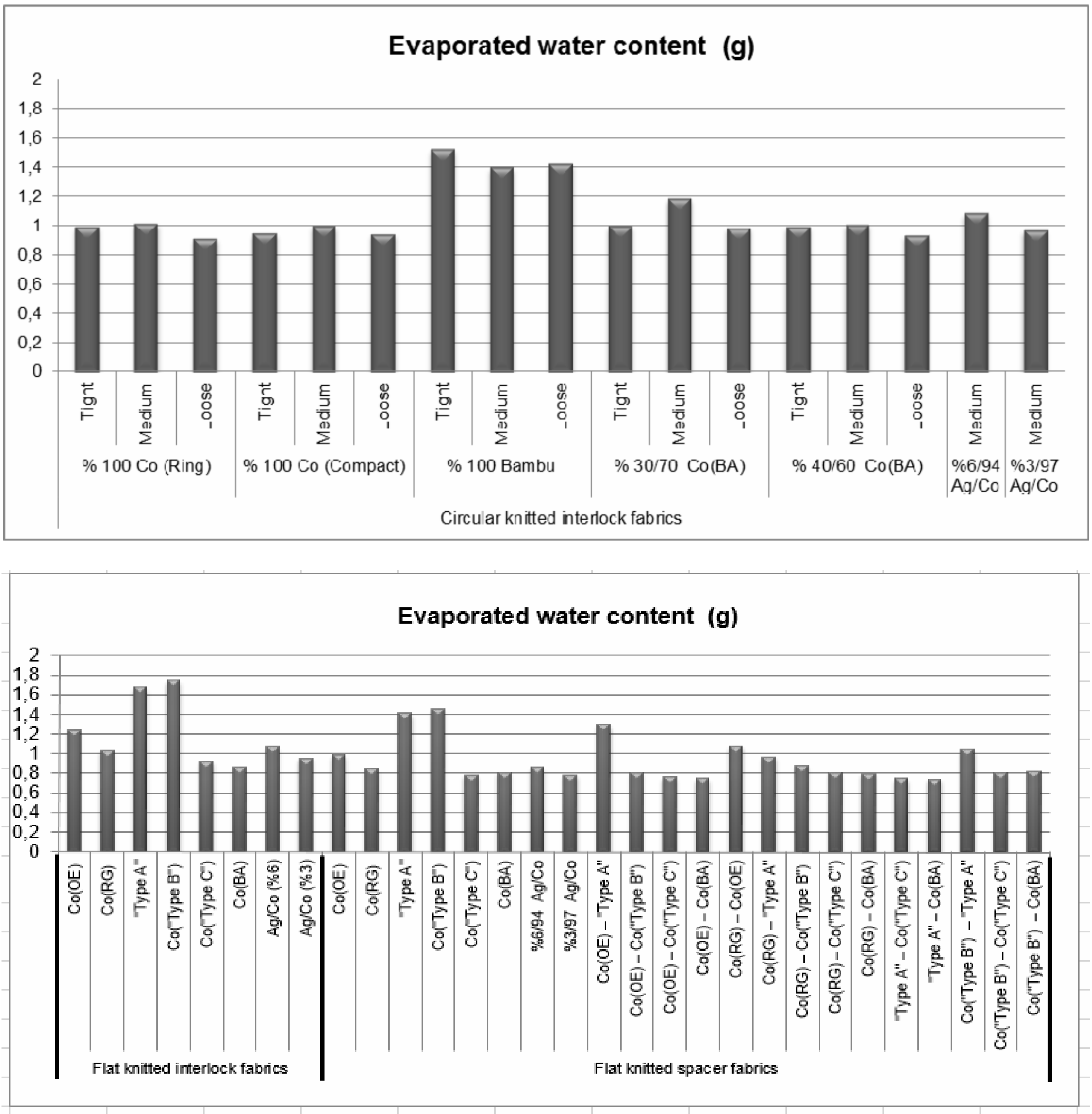


Figure 4. Evaporated water content of the fabrics

4. CONCLUSION

This study aims to determine functional knitted fabrics that will be appropriate for footwear linings of patients with locomotor disorders caused by diabetes and arthritis. For this purpose, several types of fabrics were produced by using special yarns in two different knitted structures (interlock and flat knitted spacer fabrics). In order to select the fabrics that have the optimum characteristics, in terms of the related footwear standard, extensibility (as high as possible), friction coefficient (≥ 0.7), tensile strength (≥ 2N/mm^2), tensile elongation (≥ 80%) and water vapour permeability (as high as possible) parameters were evaluated.

The results revealed that, from these properties point of view, the fabrics which meet the requirements for the established end use, from various groups, are:

- For circular knitted interlock fabrics, the 100% cotton (ring) fabric in three tightness, tight 100% cotton (compact) fabric and 40/60% cotton/bamboo fabric.
- For flat knitted interlock fabrics, only Cotton/“Type C” fabric has been found as suitable for linings.
- In case of flat knitted spacer fabrics including cotton, bamboo, the “Type B” and “Type C”, (Co(OE), Co(Ring), Co(OE)-Co(“Type B”), Co(OE)-“Type A”, Co(OE)-Co(“Type C”), Co(OE)-Co(BA), Co(Ring)- Co(OE), Co(Ring)-Co(BA), Co(Ring)- Co(“Type C”)) were found appropriate for this usage.

All fabric structures produced by using cotton/silver blends provide the optimum performance parameters for footwear linings.

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