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COMPARISON AND ASSESSMENT OF SELECTED PARAMETERS OF CHROME-FREE AND CHROME-TANNED LEATHER

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COMPARISON AND ASSESSMENT OF SELECTED PARAMETERS OF CHROME-FREE AND CHROME-TANNED LEATHER

ABSTRACT. In the leather tanning industry, decision-makers act resolutely to eliminate chrome as a tanning agent due to its negative effect on human health and the natural environment. Considering this, it makes sense to research opportunities to use chrome-free leather as a substitute for chrome-tanned leather. This paper demonstrates research on the mechanical and hygienic properties of leather tanned with glutaraldehyde as well as chrome-tanned leather, intended for shoe uppers. The results of the tensile strength and percentage extension measurements made by the Instron tensile machine, and the results of water vapour permeability measurements made by a moisture analyser, have been analysed using Statistica. The statistical data analysis has been performed using the following tests: Kolmogorov-Smirnov with Lilliefors correction, Shapiro-Wilk, T, Levene, Brown and Forsythe, Fisher-Snedecor, and Cochran-Cox. Regarding mechanical parameters, no statistically significant difference has been observed between chrome-free and chrome-tanned leather in dry conditions. However, such differences have been observed in wet samples. The tests showed higher stability of mechanical parameters of leather tanned with modified glutaraldehyde compared to chrome-tanned leather. Leather tanned with a chrome tanning agent, tested in both dry and wet conditions, showed significant differences between them, considering their tensile strength and percentage extension. The hygienic properties of both types of leather being researched are more or less similar – the research has not found any statistically significant differences for water vapour permeability.
KEY WORDS: chrome-free leather, chrome-tanned leather, glutaraldehyde, leather quality

COMPARAȚIA ȘI EVALUAREA ANUMITOR PARAMETRI ÎN CAZUL PIEILOR FĂRĂ CROM ȘI TĂBĂCITE ÎN CROM

REZUMAT. În industria de pielărie, factorii decizionali acționează cu hotărâre pentru a elimina cromul ca agent de tăbăcire din cauza efectului său negativ asupra sănătății umane și asupra mediului. Având în vedere acest lucru, este logic să cercetăm oportunități de a înlocui pielea tăbăcită în crom cu piele fără crom. Această lucrare prezintă cercetările privind proprietățile mecanice și igienice ale pielii tăbăcite cu glutaraldehidă precum și ale pielii tăbăcite în crom, destinate fețelor de încălțăminte. S-au analizat cu ajutorul programului Statistica rezultatele măsurătorilor de rezistență la rupere și alungire procentuală efectuate utilizând mașina de tracțiune Instron și rezultatele măsurătorilor de permeabilitate la vapori de apă efectuate cu un analizor de umiditate. Analiza datelor statistice a fost efectuată folosind următoarele teste: Kolmogorov-Smirnov cu corecție Lilliefors, Shapiro-Wilk, test T, Levene, Brown și Forsythe, Fisher-Snedecor și Cochran-Cox. În ceea ce privește parametrii mecanici, nu s-a observat nicio diferență semnificativă din punct de vedere statistic între pielea fără crom și cea tăbăcită în crom în condiții uscate. Cu toate acestea, astfel de diferențe au fost observate în probele umede. Testele au arătat o stabilitate mai mare a parametrilor mecanici ai pielii tăbăcite cu glutaraldehidă modificată comparativ cu pielea tăbăcită în crom. Pieile tăbăcite cu un agent de tăbăcire pe bază de crom, testate atât în condiții uscate, cât și umede, au prezentat diferențe semnificative între ele, în ceea ce privește rezistența la rupere și alungirea procentuală. Proprietățile igienice ale ambelor tipuri de piele cercetate sunt mai mult sau mai puțin similare – nu s-au găsit diferențe semnificative din punct de vedere statistic pentru permeabilitatea la vapori de apă.
CUVINTE CHEIE: piele fără crom, piele tăbăcită în crom, glutaraldehidă, calitatea pielii

COMPARAISON ET ÉVALUATION DE PARAMÈTRES SÉLECTIONNÉS DES CUIRS SANS CHROME ET TANNÉ AU CHROME

RÉSUMÉ. Dans l'industrie du tannage du cuir, les décideurs agissent résolument pour éliminer le chrome comme agent de tannage en raison de son effet négatif sur la santé humaine et l'environnement. Compte tenu de cela, il est logique de rechercher des opportunités d'utiliser du cuir sans chrome comme substitut du cuir tanné au chrome. Cet article présente des recherches sur les propriétés mécaniques et hygiéniques des cuirs tannés au glutaraldéhyde ainsi que des cuirs tannés au chrome, destinés aux tiges pour les chaussures. Les résultats des mesures de résistance à la traction et de pourcentage d'allongement effectuées par la machine de traction Instron, ainsi que les résultats des mesures de perméabilité à la vapeur d'eau effectuées par un analyseur d'humidité, ont été analysés à l'aide du logiciel Statistica. L'analyse statistique des données a été réalisée à l'aide des tests suivants : Kolmogorov-Smirnov avec correction de Lilliefors, Shapiro-Wilk, T, Levene, Brown et Forsythe, Fisher-Snedecor et Cochran-Cox. Concernant les paramètres mécaniques, aucune différence statistiquement significative n'a été observée entre le cuir sans chrome et le cuir tanné au chrome en conditions sèches. Cependant, de telles différences ont été observées dans des échantillons humides. Les tests ont montré une plus grande stabilité des paramètres mécaniques du cuir tanné avec du glutaraldéhyde modifié par rapport au cuir tanné au chrome. Le cuir tanné avec un agent de tannage au chrome, testé dans des conditions sèches et humides, a montré des différences significatives entre eux, compte tenu de leur résistance à la traction et de leur pourcentage d'allongement. Les propriétés hygiéniques des deux types de cuir étudiés sont plus ou moins similaires – la recherche n'a trouvé aucune différence statistiquement significative pour la perméabilité à la vapeur d'eau.
MOTS CLÉS : cuir sans chrome, cuir tanné au chrome, glutaraldéhyde, qualité du cuir

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INTRODUCTION

With the effect of tanning, raw hide is transformed to tanned leather with appropriate mechanical strength and resistance to a number of factors, both biological and physical [1]. The terms which are often present in the literature and presented as opposites, are "*wet-blue leather*", and "*wet-white leather*", which are related to the type of tanning agent used. Both terms refer to leather at an intermediate stage of manufacturing, in a wet condition, yet the former indicates chrome-tanned leather. In contrast, the latter refers to leather tanned by using, for example, zirconium or aluminum salts, modified aldehydes, glutaraldehydes, or syntans [2], i.e., using no chrome. Despite the high popularity of the chrome tanning method, which allows the production of soft and light leather with high thermal resistance and high antimicrobial resistance [1], it is being criticised more frequently. This stems from the fact that chrome has an undesirable effect on the human body as well as the fact that once the tanning process is completed, certain amounts of such element infiltrate into wastewater and therefore into the environment, often at a concentration exceeding permissible limits, which was confirmed, among others, by Asfaw *et al*. [3] or Omm-e-Hany *et al*. [4]. Research is currently underway for the recovery of Cr (VI) from tannery sludge and chrome-tanned leather shavings [5].

Basic chromium sulfate is currently the most popular tanning agent used in leather manufacturing [6, 7]. During chrome tanning, the once trivalent chrome salt - Cr (III), is introduced into the hide, and a cross-linking reaction between collagen and such a tanning agent is induced [1]. Chrome at the sixth oxidation number - Cr (VI), is believed to be highly dangerous; however, it is not used for tanning. However, in some hide processing phases, under favourable conditions (such as elevated pH during neutralisation of wet-blue leather, and the use of fatliquoring agents comprising non-saturated fat acids), it may happen that Cr (III) is oxidated to Cr (VI) [6]. The presence of Cr (VI) in leather has been confirmed in many studies [8-10], as well as the data of the Rapid Alert System for Dangerous Non-Food Products [11].

Employees in the leather tanning industry are professionally exposed to chrome, mostly by skin exposure, due to which they may suffer from chrome eczema. Chrome is also believed to be a strong allergen. Prolonged contact with this element may be a cause septum perforation or even loss of smell or taste. Its harmful effect on the respiratory system can cause bronchitis and an asthma attack [12]. Chrome compounds are also believed to be carcinogenic, mutagenic, embryotoxic, and teratogenic. Chrome (VI) is believed to be a procarcinogen that easily passes through and distributes throughout the organism as it may penetrate biological membranes without much difficulty. The processes related to a reduction of Cr (VI) to Cr (III), occurring in a cell, are connected to the activation of carcinogenic properties of chrome as they increase the probability that Cr (III) will act upon DNA [13]. If such reduction occurs outside a cell (or even outside a cell nucleus), the genetic activity of Cr (VI) is less [12]. Chrome, mostly hexavalent, is very hazardous to pregnant women. It rapidly penetrates the placenta to the fetus, where it accumulates, and in consequence, causes developmental defects (e.g., cleft palate, bone lesions) [13]. The issue of the harmful effect of chrome on the natural environment has also been addressed in many papers. Shanker *et al*. [14], Oliveira [15], Bhalerao, and Sharma [16] indicate, among others, the harmful effects of this element on plant seeds sprouting, their enzymatic activity and photosynthesis, and the presence of chrome is attributed to lower yields.

An example of chrome-free tanning is tanning with glutaraldehyde. It reacts with amine groups of collagens, establishing cross-link bridges. Furthermore, products of the polymerisation of glutaraldehyde, demonstrating high molecular mass, settle in the hide. Such products originate from spontaneous aldehyde polymerisation in solutions. By using this compound for tanning, one can produce leather featuring a higher sweat and alkali resistance. Such leather also feels soft, demonstrates higher fullness, and an evenly distributed shade is possible during the coloring process [17]. Leather tanned without using chrome, treated, among others, with agents such as glutaraldehyde and vegetable tanning agents, is suggested by Plavan and Gaido [18] to be used for prosthetic purposes. The researchers demonstrated that such leather manifests appropriate stability and that using glutaraldehyde has a positive effect on such leather's resistance to ageing. Due to human health protection and restriction of harmful chrome effects on the natural environment, the opportunities to substitute wet-blue leather with wet-white leather are being researched by many other scientists. The research on manufacturing technology and properties of chrome-free leather, defined as ecological substitutes for chrome-tanned leather, was presented in papers: Crudu *et al*. [19], Bacardi *et al*. [20], Raha *et al*. [21], Rosu *et al*. [22], Shi *et al*. [23].

The purpose of this paper is to compare selected mechanical and hygienic properties of chrome-free and chrome-tanned leather intended for shoe uppers. During experiments, tensile strength and percentage extension, as well as the water vapour permeability of bovine hide, which are important parameters to grain leather intended for shoe uppers, were determined.

MATERIALS AND METHODS

Tanned Leathers Used for Research

The research on mechanical and hygienic properties was performed for two types of soft, aniline-finished bovine leather intended for shoe uppers, that is:

- chrome-free ("*wet-white*") leather – tanned with modified glutaraldehyde. The average sample thickness was 1.6 ± 0.03 mm,
- chrome-tanned ("*wet-blue*") leather – tanned with trivalent chrome salt - Cr (III). The average sample thickness was 1.56 ± 0.03 mm.

The research samples were cut out of butt sections of chrome-free leather and chrome-tanned leather, respectively. The assessment of the mechanical properties was performed on both dry and wet leather, while the assessment of hygienic properties was performed only on dry leather. Dry samples included leather conditioned in an atmosphere with a relative ambient humidity of 50% (± 5.0%) and an air temperature of 23ºC (± 2.0ºC). Wet samples were obtained by placing dry samples in water at an ambient temperature (temperature not monitored continuously, approx. 22-25ºC) for 24h. Directly before the test, the samples were put on a paper towel to remove excess water. The reason for performing two research variants, i.e., using dry and wet samples, is that leather moisture content significantly affects its mechanical parameters [24]. Water present in spaces between fibers relaxes the leather structure, therefore decreasing mutual attraction and friction between collagen fibrils [25], consequently affecting leather resistance and stretching.

Research Methods for Mechanical Properties

The basis for the preparation of laboratory samples for tensile strength and percentage extension tests was the ISO 3376:2011 Standard [26]. According to the mentioned standard, it was assumed that the sample size for soft leather, i.e., a length of an oar-shaped sample, was 110 mm, and the width of the tested section (subjected to tensile forces) was 10 mm. Mechanical properties tests were performed on both dry and wet samples. Before testing, dry samples were conditioned in an atmosphere with a relative ambient humidity of 50% (± 5.0%) and an air temperature of 23°C (± 2.0°C), according to the guidelines of the ISO 2419:2012 Standard [27].

For the purpose of statistical analysis, the number of samples was increased, compared to the ISO 3376:2011 Standard [26] recommendation. The following was used for research:

- 12 dry samples acquired from chrome-free leather (6 parallel and 6 perpendicular to the backbone),
- 12 wet samples acquired from chrome-free leather (6 parallel and 6 perpendicular to the backbone),
- 12 dry samples acquired from chrome-tanned leather (6 parallel and 6 perpendicular to the backbone),
- 12 wet samples acquired from chrome-tanned leather (6 parallel and 6 perpendicular to the backbone).

Mechanical properties tests were performed by the Instron 5544 Testing Machine, in accordance with the ISO 3376:2011 Standard [26] guidelines. Once a sample was clamped, it was subject to tensile stress at a velocity of 100 ± 20 mm/min until rupture. Based on measurement data, the tensile strength in megapascals and the percentage extension of the tested section was calculated.

Research Methods for Hygienic Properties

In order to test the hygienic properties of the material being researched, 6 circle-shaped samples with a diameter of 54 ± 2 mm were cut out of both chrome-free and chrome-tanned leather. Water vapour permeability measurements were performed by a testing set shown in Fig. 1, composed of a sampler and the MAC 50 Moisture Analyser. The moisture analyser, being a measurement device, comprises of the following: scales with a 1 mg accuracy, a drying chamber fitted with a halogen system, a temperature sensor, and processing systems with a digital display [28].

Figure 1. Water vapour permeability testing set for tanned leather: 1 – sampler, 2 – moisture analyser

Before testing, samples were conditioned in an atmosphere with a relative ambient humidity of 50% (± 5.0%) and an air temperature of 23ºC (± 2.0ºC). Such parameters were established since, in accordance with the recommendations of the equipment manufacturer, the relative humidity of the space where the test is being performed should be within 40% to 60%, and the temperature should be within 21ºC to 26ºC. After conditioning, a sample was placed in the sampler, with the flesh side facing the water. The measurements were performed at 40ºC for 1h. During a testing cycle, the equipment recorded the water mass that infiltrated through the leather sample tested. Its evaporation was caused by the generation and rise of water vapour pressure, initiated by a rise in water temperature inside the sampler [28].

Statistical Data Analysis

The statistical analysis was performed using *Statistica 13*. As the measurement results were analysed, the following hypotheses were initially verified:

- a hypothesis concerning the conformity of empirical distributions with a normal distribution, checked by the Kolmogorov-Smirnov test with Lilliefors correction, and the Shapiro-Wilk test,
- a hypothesis concerning the homogeneity of variance, checked by the T-test, the Levene test and the Browne and Forsythe test.

At the next stage, there was an attempt to verify a substantive hypothesis concerning the variation of levels of selected parameters, depending on the tanning agent used. Such verification was performed by a one-way analysis of variance using the Fisher-Snedecor test. Statistical inference was drawn at the significance level $\alpha = 0.05$. In the case it was necessary to reject the hypothesis of the homogeneity of variance, a test with independent variance estimation was applied. Individual variance assessments in the groups being researched established a basis for the use of the Cochran-Cox test.

RESULTS AND DISCUSSION

Comparison of the Mechanical Properties of Leather

Mechanical properties are among the essential values that are often verified during the evaluation of the quality and suitability of leathers for various types of use. Moreover, particularly in the case of leather intended for shoe uppers (although not exclusively), the stability of parameters of tanned leather is important, notwithstanding ambient conditions. Excessive stretching, as well as too low susceptibility to tensile force, are not desired in such tanned products. Fig. 2 shows a testing diagram for mechanical properties of both chrome-free and chrome-tanned leather that, aimed to:

I – determine the possible effects of a tanning agent on indicated properties,

II – verify the stability of these properties depending on variances of the water content in the material.

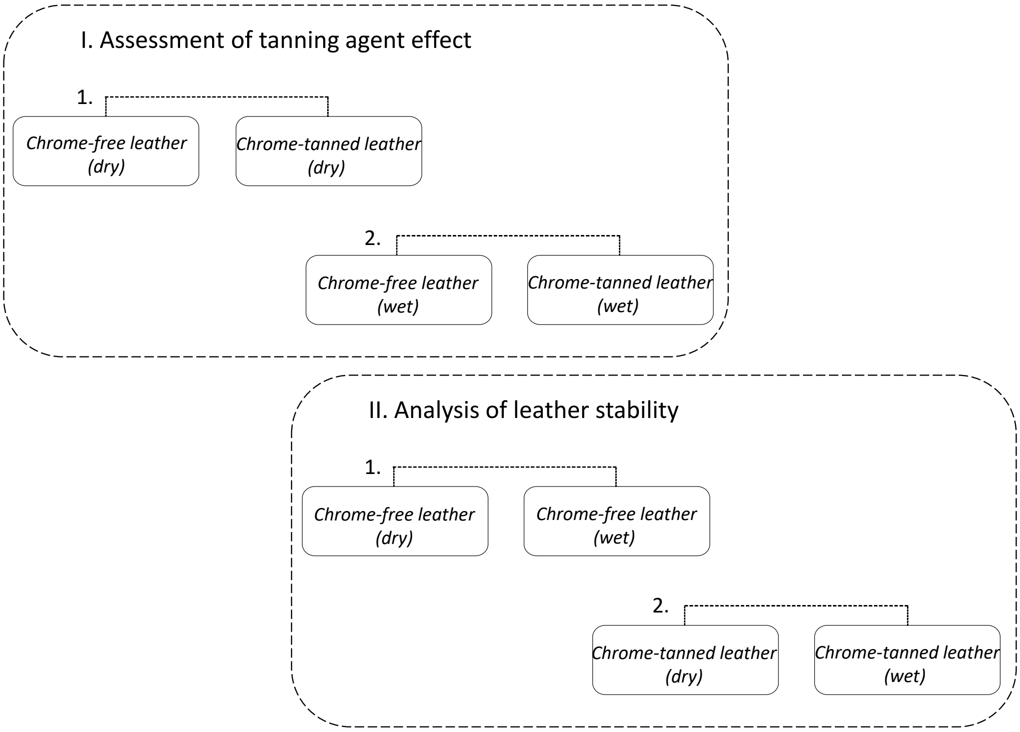

Figure 2. A testing diagram for mechanical parameters for chrome-free and chrome-tanned leather in both wet and dry conditions

Assessment of the Effects of Tanning Agents

1. Preliminary Analysis

The values of mechanical parameters, i.e., tensile strength and percentage extension obtained for samples of dry leather - both chrome-free and chrome-tanned, are shown in Tables 1 and 2, respectively. The results are collated with the appropriate division of samples parallel to the backbone and those which are perpendicular.

As shown in Table 1, the dry chrome-free leather samples cut out in parallel to the backbone have demonstrated a higher mean tensile strength and a lower mean percentage extension compared to the samples cut out perpendicularly to the backbone. In the case of results for dry chrome-tanned leather (Table 2), one can observe varied sample susceptibility to tensile forces, depending on orientation to the backbone. Also, in this case, the samples cut out along the backbone may be attributed with higher mean tensile strength and lower mean percentage extension.

Table 1: Mechanical parameter values for chrome-free leather (dry)

Bovine chrome-free leather (dry)			
Sample	Thickness, mm	Tensile strength, MPa	Extension, %
Parallel to the backbone			
1	1.61	18.59	45.66
2	1.57	18.49	61.66
3	1.58	17.71	66.00
4	1.60	16.89	51.34
5	1.63	15.49	53.00
6	1.69	15.57	40.66
$\overline{x}$ [a/]	1.61	17.12	53.05
s_d [b/]	0.04	1.26	8.69
Perpendicular to the backbone			
1	1.66	17.63	67.00
2	1.70	13.39	63.34
3	1.67	14.15	55.34
4	1.59	13.48	64.66
5	1.60	12.90	57.34
6	1.62	15.67	64.00
$\overline{x}$ [a/]	1.64	14.54	61.95
s_d [b/]	0.04	1.64	4.16

[a/]arithmetic average, [b/]standard deviation

Table 2: Mechanical parameter values for chrome-tanned leather (dry)

Bovine chrome-tanned leather (dry)			
Sample	Thickness, mm	Tensile strength, MPa	Extension, %
Parallel to the backbone			
1	1.58	18.63	47.34
2	1.59	18.09	48.34
3	1.56	16.60	55.34
4	1.58	18.60	48.66
5	1.57	19.00	51.66
6	1.54	15.92	50.34
$\overline{x}$ [a/]	1.57	17.81	50.28
s_d [b/]	0.02	1.14	1.81
Perpendicular to the backbone			
1	1.50	16.26	65.34
2	1.52	13.18	64.34
3	1.53	16.91	63.00
4	1.48	13.13	66.00
5	1.53	13.63	69.00
6	1.51	16.09	61.34
$\overline{x}$ [a/]	1.51	14.87	64.84
s_d [b/]	0.02	1.58	2.41

[a/]arithmetic average, [b/]standard deviation

The results obtained in the tests for chrome-free and chrome-tanned leather, confirm a relationship already described upon in the relevant literature [25, 29]. In the case of both types of leather subjected to testing, there is a variation of mechanical properties in relation to the orientation (to the backbone) of samples, despite the fact that leather is a complicated spatial structure with its mechanical properties affected by many factors [30]. Furthermore, based on the preliminary analysis of the obtained parameter values, it was established that there are relatively few differences between the dry samples of chrome-free and chrome-tanned leather tested in relation to the mean tensile strength and percentage extension.

The values of tensile strength and percentage extension obtained for samples of wet leather, both chrome-free and chrome-tanned, are shown in Tables 3 and 4, respectively. The results are collated with the appropriate division of samples parallel to the backbone and those which are perpendicular.

The results of measurements performed on wet chrome-free leather samples also indicate a variety of tensile strength parameter values depending on the orientation of the samples in relation to the backbone (Table 3). In this case, the observed difference between the mean results for samples cut out along the backbone and across the backbone was less in comparison to dry chrome-free leather, particularly in reference to percentage extension (Tables 1 and 3).

Table 3: Mechanical parameter values for chrome-free leather (wet)

Bovine chrome-free leather (wet)			
Sample	Thickness, mm	Tensile strength, MPa	Extension, %
Parallel to the backbone			
1	1.67	16.39	47.66
2	1.73	15.74	57.34
3	1.75	17.09	60.00
4	1.70	16.92	56.34
5	1.68	15.71	48.34
6	1.78	16.02	58.34
$\bar{x}$ [a/]	1.72	16.31	54.67
s_d [b/]	0.04	0.54	4.85
Perpendicular to the backbone			
1	1.62	13.55	58.66
2	1.75	14.30	52.34
3	1.80	14.37	59.34
4	1.70	13.59	63.34
5	1.63	14.28	57.66
6	1.71	13.69	54.00
$\bar{x}$ [a/]	1.70	13.96	57.56
s_d [b/]	0.06	0.36	3.60

[a/]arithmetic average, [b/]standard deviation

Little variation in the values of mechanical properties can also be observed in wet chrome-tanned leather cut out in two different directions (Table 4). Also, in the case of these leather samples, the differences in tensile strength and percentage extension between the samples cut out in parallel and those cut out perpendicularly to the backbone are less when compared to dry leather (Table 2). Furthermore, test results obtained for wet leather – a higher tensile strength and a lower percentage extension in samples taken along the backbone – comply with previous findings presented in the literature [25, 29]. Based on the preliminary analysis of parameter values, it was established that the results for samples of wet chrome-free and chrome-tanned leather indicate a higher difference in mean tensile strength and mean percentage extension between these samples when compared to dry leather samples.

Table 4: Mechanical parameter values for chrome-tanned leather (wet)

Bovine chrome-tanned leather (wet)			
Sample	Thickness, mm	Tensile strength, MPa	Extension, %
Parallel to the backbone			
1	1.53	16.61	69.34
2	1.53	19.88	54.00
3	1.49	17.43	57.66
4	1.50	19.36	60.66
5	1.64	19.81	90.00
6	1.54	18.90	60.71
$\bar{x}$ a/	1.54	18.67	65.38
s_d b/	0.05	1.23	11.94
Perpendicular to the backbone			
1	1.68	18.55	61.66
2	1.57	16.52	72.66
3	1.64	17.29	64.00
4	1.54	17.69	69.34
5	1.57	17.37	72.34
6	1.63	16.63	64.66
$\bar{x}$ a/	1.61	17.34	67.44
s_d b/	0.05	0.68	4.24

a/arithmetic average, b/standard deviation

According to the Polish Standard P-22225 [31], tensile strength for soft, tanned grain leather intended for shoe uppers should not be less than 13 MPa, and its maximum percentage extension should fall within 30% ÷ 90%. The results obtained for the chrome-free and chrome-tanned leathers tested, both dry and wet samples, demonstrate that these samples comply with the requirements of the indicated Standard [31]. The samples being analysed also conform to qualitative requirements recommended for natural leather for shoe uppers by the Instytut Przemysłu Skórzanego in Łódź. According to this research unit, the tensile strength for leather of such purpose should be no less than 12 MPa, while its maximum percentage extension should be no less than 40% [32].

2. Statistical Analysis

The data provided in Tables 1-4 were a basis for the analysis aiming to confirm or exclude statistically significant differences between the values of mechanical properties for leather tanned with modified glutaraldehyde (i.e., chrome-free) and chrome-tanned leather. The first stage included a comparison of values of tensile strength and percentage extension in dry leather samples. The analysis of data acquired for dry leather tanned with modified glutaraldehyde and dry chrome-tanned leather demonstrated that the empirical distribution of values of mechanical parameters is a distribution close to normal (with $p > \alpha$ where $\alpha = 0.05$). The results are shown in Table 5.

Table 5: Test results for the hypothesis concerning the normal distribution of the values of mechanical parameters for dry chrome-free and chrome-tanned leather

Dry leather	Tensile strength			Extension		
	Test statistic					
	Kolmogorov-Smirnov	Lilliefors	Shapiro-Wilk	Kolmogorov-Smirnov	Lilliefors	Shapiro-Wilk
chrome-free	d = 0.145 p > 0.20	p > 0.20	W = 0.922 p = 0.30	d = 0.188 p > 0.20	p > 0.20	W = 0.913 p = 0.23

Dry leather	Tensile strength			Extension		
	Test statistic					
	Kolmogorov-Smirnov	Lilliefors	Shapiro-Wilk	Kolmogorov-Smirnov	Lilliefors	Shapiro-Wilk
chrome-tanned	d = 0.172 p > 0.20	p > 0.20	W = 0.899 p = 0.16	d = 0.185 p > 0.20	p > 0.20	W = 0.883 p = 0.10

In reference to the dry leather samples tested, the next step included the verification of the homogeneity of variance and the determination of the level of mechanical parameters variation, dependent on the type of tanning agent used. Based on the values and probability levels for the following tests: T, Levene, and Browne and Forsythe (Table 6), it was established that the hypothesis on the homogeneity of variance could not be rejected.

The results of a one-way analysis of variance using the Fisher-Snedecor test ($F = 1.067$ with $p = 0.916$ for tensile strength, and $F = 1.114$ with $p = 0.861$ for percentage extension) confirm that the tanning method did not significantly affect the mechanical parameters of the dry leathers tested. Tensile strength and percentage extension values for both types of leather tested do not indicate any significant differences between them. Similar conclusions were also provided by Chakraborty *et al*. [33].

Table 6: Test results for the hypothesis concerning the homogeneity of variance for dry chrome-free and chrome-tanned leather (mechanical parameters)

Dry leather	Tensile strength			Extension		
	Test statistic					
	T	Leven (1, df)	Brown and Forsyth (1, df)	T	Leven (1, df)	Brown and Forsyth (1, df)
chrome-free and chrome-tanned	-0,599 p = 0.555	0.016 p = 0.900	0.004 p = 0.947	-0,017 p = 0.986	0.051 p = 0.824	0.043 p = 0.838

In the next stage, the comparison concerned the results obtained for wet leather – both chrome-free and chrome-tanned. It was established whether there are statistically significant differences between the values of mechanical parameters for both types of leather. The analysis showed that the empirical distribution of values of mechanical parameters obtained for wet leather is a distribution close to normal (with $p > \alpha$ where $\alpha = 0.05$). The results are shown in Table 7.

Table 7: Test results for the hypothesis concerning the normal distribution of the values of mechanical parameters for wet chrome-free and chrome-tanned leather

Wet leather	Tensile strength			Extension		
	Test statistic					
	Kolmogorov-Smirnov	Lilliefors	Shapiro-Wilk	Kolmogorov-Smirnov	Lilliefors	Shapiro-Wilk
chrome-free	d = 0.20 p > 0.20	p < 0.15	W = 0.894 p = 0.13	d = 0.186 p > 0.20	p > 0.20	W = 0.928 p = 0.36
chrome-tanned	d = 0.183 p > 0.20	p > 0.20	W = 0.897 p = 0.15	d = 0.170 p > 0.20	p > 0.20	W = 0.894 p = 0.13

In reference to the wet leather tested (both chrome-free and chrome-tanned), the homogeneity of variance was verified as well (using the T-test, the Levene test, and the Browne and Forsythe test). In this case, the results obtained (Table 8) indicated that the homogeneity of variance hypothesis should be rejected.

Table 8: Test results for the hypothesis concerning the homogeneity of variance for wet chrome-free and chrome-tanned leather (mechanical properties)

Wet leather	Tensile strength			Extension		
	Test statistic					
	T	Leven (1, df)	Brown and Forsyth (1, df)	T	Leven (1, df)	Brown and Forsyth (1, df)
chrome-free and chrome-tanned	-5,476 p = 0.000	0,206 p = 0.654	0,299 p = 0.590	-3.391 p = 0.002	2.898 p = 0.103	2.159 p = 0.156

Due to the need to reject the homogeneity of variance hypothesis, analysis with an independent variance estimation was performed using the Cochran-Cox test. The value of this statistic was -5.476, with a probability level of p = 0.00002 for tensile strength and -3.391, with a probability level of p = 0.0026 for percentage extension. Based on the results obtained, it was established that there are statistically significant differences between the values of mechanical parameters for wet chrome-free and chrome-tanned leather, while higher values of the analysed parameters, i.e., tensile strength and percentage extension, were found in chrome-tanned leather (cf. Table 3 and Table 4).

Assessment of Leather Stability

Further analyses were performed with the purpose of assessing the material stability by confirming or excluding the occurrence of statistically significant differences between dry and wet leather samples. First, the leather samples tanned with modified glutaraldehyde were taken into consideration. The results related to testing the hypothesis concerning the homogeneity of variance are shown in Table 9.

Table 9: Test results for the hypothesis concerning the homogeneity of variance for dry and wet chrome-free leather (mechanical properties)

Dry and wet leather	Tensile strength			Extension		
	Test statistic					
	T	Leven (1, df)	Brown and Forsyth (1, df)	T	Leven (1, df)	Brown and Forsyth (1, df)
chrome-free	0.998 p = 0.334	2.579 p = 0.123	2.064 p = 0.165	0.495 p = 0.626	4.728 p = 0.041	4.167 p = 0.053

Based on the obtained values of test statistics and corresponding probability levels, the homogeneity of variance hypothesis cannot be rejected. Furthermore, based on the results of the one-way analysis of variance using the Fisher-Snedecor test ($F = 2.396$ with $p = 0.163$ for tensile strength and $F = 3.258$ with $p = 0.062$ for percentage extension) it was established that, for leather tanned with modified glutaraldehyde, the values of the tested mechanical parameters do not vary significantly regardless of whether it is dry or wet leather.

Following this, a similar comparative analysis was performed for chrome-tanned leather samples, both dry and wet. As in previous cases, this analysis compared the values of tensile strength and percentage extension. Based on the obtained results of the test statistics provided in Table 10, it was established that the homogeneity of variance hypothesis should be rejected. Due to this, an analysis with independent variance estimation was performed using the Cochran-Cox test. The value of this statistic was -2.360, with a probability level of p=0.03 for tensile strength, and -2.478, with a probability level of p=0.022 for percentage extension. Based on the results obtained, it was established that there are statistically significant differences between the values of mechanical parameters for dry and wet chrome-tanned leather. The higher values of the analysed parameters, i.e., tensile strength and percentage extension, were found in wet leather samples (cf. Table 2 and Table 4).

Table 10: Test results for the hypothesis concerning the homogeneity of variance for dry and wet chrome-tanned leather (mechanical properties)

Dry and wet leather	Tensile strength			Extension		
	Test statistic					
	T	Leven (1, df)	Brown and Forsyth (1, df)	T	Leven (1, df)	Brown and Forsyth (1, df)
chrome-tanned	-2.462 p = 0.023	0.053 p = 0.166	2.063 p = 0.165	-2.478 p = 0.021	0.033 p = 0.856	0.093 p = 0.763

Comparison of Hygienic Properties of Leathers

A comparative analysis for chrome-free and chrome-tanned leather was also performed in relation to hygienic properties, important due to the fact that such leather is intended for shoe uppers. The analysis tested the water vapour permeability of leather samples, and then statistical analysis was conducted to estimate whether such parameter values show any significant differences depending on the tanning agent selection.

Comparing the measurement results, as shown in Table 11, one may observe little difference between the mean water vapour permeability value for chrome-free and chrome-tanned leather. Also, in case of this parameter, both leather types conform to qualitative requirements recommended by the Instytut Przemysłu Skórzanego in Łódź. According to these guidelines [32], water vapour permeability for natural shoe uppers leather should be no less than 1.0 mg/cm^{2}h.

Table 11: Measurement results for the water vapour permeability of chrome-free and chrome-tanned leather

Water vapour permeability, mg/cm^2		
Sample	Chrome-free leather	Chrome-tanned leather
1	15.40	15.40
2	15.30	15.60
3	15.20	15.40
4	15.10	15.35
5	15.40	15.50
6	15.50	15.40
$\bar{x}^{a/}$	15.32	15.44
$s_d^{b/}$	0.317	0.084

$^{a/}$arithmetic average, $^{b/}$standard deviation

Statistical analysis of data acquired for leather tanned with modified glutaraldehyde and chrome-tanned leather demonstrated that the empirical distribution of values of the tested parameter is close to a normal distribution. The results are shown in Table 12.

In reference to the leather samples tested, the next step included verification of the homogeneity of variance and determination of the level of water vapour permeability value variation depending on the tanning agent selected. Based on the values and probability levels for the following tests: T, Levene, and Browne and Forsythe (Table 13), it was established that the hypothesis on the homogeneity of variance could not be rejected.

The result of a one-way analysis of variance using the Fisher-Snedecor test (F = 2.574 with p = 0.323), in reference to water vapour permeability, indicates that the values of the tested parameter do not show any significant differences between chrome-free and chrome-tanned leather.

Table 12: Test results for the hypothesis concerning the normal distribution of the values of water vapour permeability for chrome-free and chrome-tanned leather

Leather	Water vapour permeability Test statistic		
	Kolmogorov-Smirnov	Lilliefors	Shapiro-Wilk
chrome-free	d = 0.214 p > 0.20	p > 0.20	W = 0.958 p = 0.80
chrome-tanned	d = 0.341 p > 0.20	p < 0.05	W = 0.847 p = 0.15

Table 13: Test results for the hypothesis concerning the homogeneity of variance for chrome-free and chrome-tanned leather (water vapour permeability)

Leather	Water vapour permeability Test statistic		
	T	Leven (1, df)	Brown and Forsyth (1, df)
chrome-free and chrome-tanned	-1.765 p = 0.108	1.582 p = 0.237	1.561 p = 0.240

SUMMARY AND CONCLUSIONS

While the leather manufacturing technology using chrome tanning is fully developed, and the properties of such leather are well known and researched, the research on products tanned with alternative and more environment-friendly tannins is underway. One may point to examples in the literature – Chakraborty *et al*. [33] or Rachmawati and Anggriyani [34], which indicate satisfactory effects in reference to the values of mechanical parameters, i.e., tensile strength and percentage extension, that may be achieved by using modified glutaraldehyde as a tanning agent. Conducting works aiming to obtain leather with parameters close to chrome-tanned leather seems to be necessary and well justified, considering the harmfulness of chrome with respect to its negative influence on human health and the natural environment, thus having life quality improvement in mind.

The research concerning the basic mechanical and hygienic parameters, significant due to the material being fit for use in shoe uppers as well as the final product quality, conducted for chrome-free and chrome-tanned leather as well as their statistical analysis allowed to formulate the following conclusions:

1) Leathers tanned with modified glutaraldehyde and chrome-based tanning agent, tested in a dry condition, do not show significant differences between them, considering their tensile strength and percentage extension.
2) Leathers tanned with modified glutaraldehyde and chrome-based tanning agent, tested in a wet condition, show significant differences between them, considering their tensile strength and percentage extension. Higher values of the mentioned parameters are present in leather tanned with a chrome-based tanning agent.
3) Leathers tanned with modified glutaraldehyde, tested in both dry and wet conditions, do not show significant differences between them, considering their tensile strength and percentage extension. This confirms that such leather is stable under the conditions provided during the experiment.
4) Leathers tanned with a chrome-based tanning agent, tested in both dry and wet conditions, showed significant differences between them, considering their tensile strength and percentage extension. Higher values of the mentioned parameters are present in wet leather. This confirms chrome-tanned leather is less stable in comparison to chrome-free leather.
5) Leathers tanned with modified glutaraldehyde and chrome-based tanning agents do not show significant

differences between them, considering their water vapour permeability, a parameter that demonstrates its hygienic properties.

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DOES INSOLE HARDNESS AFFECT THE DYNAMIC POSTURAL STABILITY OF BASKETBALL ATHLETES DURING JUMP LANDING?

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DOES INSOLE HARDNESS AFFECT THE DYNAMIC POSTURAL STABILITY OF BASKETBALL ATHLETES DURING JUMP LANDING?

ABSTRACT. This study aimed to examine the effects of shoe insole hardness on the dynamic postural stability of basketball athletes during jump landing manoeuvres. Twenty college basketball athletes were recruited to complete a single-leg jump landing task on a force plate in three insole conditions (soft-, rigid- and no-insole). Kistler force plate and Pedar-X insole system were used to collect the ground reaction force (GRF) and plantar pressure data. Dynamic Postural Stability Index (DPSI), Anterior-Posterior Stability Index (APSI), Medial-Lateral Stability Index (MLSI), and Vertical Stability Index (VSI) were then calculated from GRF data. DPSI, APSI, MLSI, and VSI were statistically conducted among the three insole conditions by a one-way ANOVA with repeated measures. MLSI were decreased when wearing soft- and rigid insoles compared with no-insole condition ($p < 0.05$). However, there were no significant differences in APSI and VSI among the three insole conditions. In the midfoot region, contact areas were increased in the soft- and rigid insole than the no-insole condition ($p < 0.0001$). Dynamic balance of basketball athletes in the medial-lateral direction could be enhanced by wearing insoles during jump landings tasks. However, the postural stability of basketball athletes did not increase with insole hardness increasing.

KEY WORDS: dynamic postural stability; jump landing; insole hardness; ankle injury

DURITATEA BRANȚULUI AFECTEAZĂ STABILITATEA POSTURALĂ DINAMICĂ A JUCĂTORILOR DE BASCHET ÎN TIMPUL ATERIZĂRII LA SĂRITURI?

REZUMAT. Acest studiu are ca scop analiza efectelor durității branțului asupra stabilității posturale dinamice a jucătorilor de baschet în timpul aterizării la sărituri. S-au recrutat douăzeci de jucători de baschet universitar care să execute o aterizare cu un singur picior pe o platormă de forță în trei situații (cu branț moale, cu branț rigid și fără branț). S-au utilizat platforma de forță Kistler și sistemul de branț Pedar-X pentru a colecta datele privind forța de reacțiune a solului (GRF) și presiunea plantară. S-au calculae apoi indicele de stabilitate posturală dinamică (DPSI), indicele anterior-posterior (APSI), indicele medio-lateral (MLSI) și indicele de stabilitate verticală (VSI) din datele GRF. S-au calculat statistic indicii DPSI, APSI, MLSI și VSI în cele trei situații utilizând analiza ANOVA unidirecțională cu măsurători repetate. Indicele MLSI e scăzut la purtarea unor branțuri moi și rigide, comparativ cu situația fără branț ($p < 0,05$). Cu toate acestea, nu au existat diferențe semnificative în cazul indicilor APSI și VSI în cele trei situații. În regiunea mediană a piciorului, zonele de contact au fost mai mari în cazul purtării branțului moale și a celui rigid decât în situația fără branț ($p < 0,0001$). Echilibrul dinamic al jucătorilor de baschet în direcția medio-laterală ar putea fi îmbunătățit prin purtarea branțurilor în timpul aterizării la sărituri. Cu toate acestea, stabilitatea posturală a jucătorilor de baschet nu a crescut odată cu creșterea durității branțului.

CUVINTE CHEIE: stabilitate posturală dinamică; aterizare la săritură; duritatea branțului; leziunea gleznei

LA DURETÉ DE LA SEMELLE INTERNE AFFECTE-T-ELLE LA STABILITÉ POSTURALE DYNAMIQUE DES JOUEURS DE BASKET LORS DE LA RÉCEPTION DES SAUTS?

RÉSUMÉ. Cette étude a le but d'examiner les effets de la dureté de la semelle interne de la chaussure sur la stabilité posturale dynamique des joueurs de basket lors de la réception des sauts. Vingt joueurs de basketball universitaire ont été recrutés pour effectuer une réception de saut à une jambe sur une plateforme de force dans trois situations (semelle souple, semelle rigide et sans semelle). La plateforme de force Kistler et le système de semelle interne Pedar-X ont été utilisés pour collecter des données sur la force de réaction au sol (GRF) et la pression plantaire. L'indice de stabilité posturale dynamique (DPSI), l'indice de stabilité antérieure-postérieure (APSI), l'indice de stabilité médiale-latérale (MLSI) et l'indice de stabilité verticale (VSI) ont ensuite été calculés à partir des données GRF. Les indices DPSI, APSI, MLSI et VSI ont été statistiquement calculés dans les trois situations par une analyse ANOVA unidirectionnelle avec des mesures répétées. L'indice MLSI a diminué lors du port de semelles souples et rigides par rapport à l'absence de semelle ($p < 0,05$). Cependant, il n'y avait pas de différences significatives en ce qui concerne l'APSI et le VSI entre les trois situations. Dans la région du médio-pied, les zones de contact ont été augmentées dans le cas du port de la semelle souple et de la semelle rigide par rapport à la situation sans semelle ($p < 0,0001$). L'équilibre dynamique des joueurs de basket dans la direction médio-latérale pourrait être amélioré par l'utilisation des semelles pendant les réceptions des sauts. Cependant, la stabilité posturale des joueurs de basket n'a pas été augmentée avec l'augmentation de la dureté de la semelle interne.

MOTS CLÉS: stabilité posturale dynamique; réception de saut; dureté de la semelle interne; blessure à la cheville

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INTRODUCTION

Ankle injuries are among the most common and severe injuries sustained in basketball games [1], which induce pain, crepitus, and instability [2]. It leads to 53.7% of the total time lost for the basketball players [3]. The tremendous jump landing manoeuvres in basketball games are one of the leading causes of ankle injuries. The immediate reason is that the landing impacts of 3.5-9 times bodyweight acting on the lower extremities, especially on the ankle joint. The elastic ankle joint might not resist those high-impact loads [1, 4].

External ankle supports (e.g., ankle brace) or internal foot orthotics (e.g., shoe insole) were commonly used to improve postural control of basketball athletes with ankle injuries [5, 6]. Ankle brace would decrease the inversion/eversion angle of the ankle joint, while limiting the range of motion (ROM) of the ankle joints in the meantime [7], which may restrict the sports performance of basketball athletes. Therefore, basketball players are reluctant to wear orthoses to participate in basketball games. Recent studies showed that internal foot orthotics such as shoe insole could increase the lateral stability of older adults via stimulating plantar proprioception and enhancing signal input of the nervous system.

The insole hardness would affect the postural stability [8-12]. Ankle motion in the medial-lateral plane is negatively related to insole hardness (soft soles cause increased ankle movement). Xingda Qu *et al*. [13] studied the effects of different insoles on postural stability in older adults and reported that rigid insole was associated with better dynamic postural stability compared to soft insole. However, to the author's best knowledge, whether insole hardness could affect the dynamic postural stability of basketball players remains unknown.

Thus, the purpose of this study was to assess the dynamic postural stability of basketball athletes during jump landings manoeuvres while wearing insoles with varying hardness. It was hypothesized that: 1) the dynamic postural stability of the basketball athletes would be improved when wearing insoles compared to no-insole conditions; 2) dynamic postural stability of basketball athletes would be improved with the insole hardness increasing.

MATERIALS AND METHODS

Participants

Twenty healthy young college basketball athletes were recruited in this study (10 males and 10 females, age: 20.3 ± 1.2 years; height: 177 ± 8.1 cm; weight: 72.3 ± 7.8 kg; BMI: 21.2 ± 2.9 kg/m^2). None of the participants had undergone back or lower limb surgery, neurological or vascular disease, or lower extremity musculoskeletal diseases in the previous six months. None of the participants consumed drugs/alcohol or engaged in strenuous physical activity within 24 hours. Within 24 hours of tests, participants should abstain from strenuous physical activity. Each participant was informed of the risks of this study before enrollment. Each participant provided written informed consent, which the University's Institutional Review Board approved (No. 102772019RT054).

Materials

All participants were required to wear a pair of traditional basketball shoes (KT3 high-top, ANTA, Quanzhou, China) with three insole conditions: (1) soft insole, (2) rigid insole, and (3) no insole. The two insoles were identical in material (EVA foam), thickness, and shape except for hardness. The insole hardness was determined using the Shore C classification system, with scores ranging from Shore C 20 (soft) to Shore C 50 (rigid). The insole thickness is 6mm, which is commonly used in commercial basketball shoes. The material and shape of the insoles were chosen for their frequent use in recreational sports. Shoe Sizes 37–43 were available for this study.

Test Protocol

A force plate (9281EA, Kistler Corporation, Switzerland) and a Pedar-X insole system (Pedar-X® system, Novel Inc, Munich, Germany) were used to collect ground reaction force (GRF) data at a sampling rate of 200 Hz during anterior-posterior (AP) jumping tasks. Wikstrom's dynamic postural stability test followed the jump protocols based on previous studies [14]. Participants were instructed to randomly complete the trial in three conditions: soft insoles, rigid insoles, and no insoles. The participants stood behind the force plate with 40% of their body height during the test, with a 30-cm hurdle put halfway between the starting position and the force plate [14]. Then they were instructed to perform the following actions: jump in the anterior direction over the hurdle using a two-footed jump, land on the force plate with their non-dominant limb, and try to maintain stability as quickly as possible, place their hands on their hips once stabilized, and remain still for 10 seconds while looking forward. The dominant leg is determined to be the preferred leg to kick the ball [15]. The trial would be discarded if the participant failed to jump or the dominant limb touched the ground. Three successful trials in each insole condition were collected, followed by two minutes of rest.

Data Reduction

Data reduction was performed using a custom MATLAB (v2016a, Natick, MA) script file for dynamic postural stability. The force plate data were filtered using a fourth-order bidirectional low pass Butterworth filter with a cutoff frequency of 50 Hz. For data reduction, three trials for each insole condition were averaged. As illustrated in Equations 1-4, the primary variable for the AP jump landing manoeuvers was the dynamic postural stability index (DPSI). DPSI was calculated from the first three seconds of ground reaction force (GRF) data following initial contact, defined as the instant the vertical GRF exceeded 10 N [14]. DPSI is a composite of anterior-posterior (APSI), medial-lateral (MLSI), and vertical (VSI) GRF that is highly reliable [14]. A lower stability index indicated that the system was balanced [16]. The following equations were used to derive these variables:

$$\mathrm{APSI} = \sqrt{\frac{\sum(0-GRF_y)^2}{number\ of\ data\ points}} \div Body\ Weight \quad (1)$$

$$\mathrm{MLSI} = \sqrt{\frac{\sum(0-GRF_x)^2}{number\ of\ data\ points}} \div Body\ Weight \quad (2)$$

$$\mathrm{VSI} = \sqrt{\frac{\sum(Body\ Weight-GRF_z)^2}{number\ of\ data\ points}} \div Body\ Weight \quad (3)$$

$$\mathrm{DPSI} = \sqrt{\frac{\sum(0-GRF_x)^2+\sum(0-GRF_y)^2+\sum(Body\ Weight-GRF_z)^2}{number\ of\ data\ points}} \div Body\ Weight \quad (4)$$

The mean plantar contact area (CA, mm^2) in three anatomical regions (masks) was calculated in this study (Novel Electronics Inc). These regions included rearfoot (RF, 0%–27%), midfoot (MF, 27%–55%), and forefoot (FF, 55%–100%) [17, 18] (Fig. 1 illustrates regions division in detail).

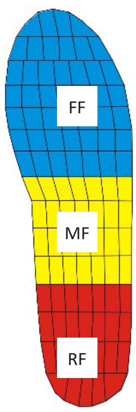

Figure 1. Three anatomical foot regions were defined in this study: FF (forefoot), MF (midfoot), RF (rearfoot)

Statistical Analysis

For APSI, MLSI, VSI, DPSI, and CA, one-way analyses of variance (ANOVA) with repeated measures were conducted. When a significant main effect was observed, LSD post hoc tests were conducted. η^2 were calculated for each ANOVA. The level of significance was set at 0.05. Intraclass correlation coefficient (ICC) and standard error of the mean (SEM) analyses were used to determine the reliability of the APSI, MLSI, VSI, and DPSI in the first 3-seconds sampling interval. All statistical analyses were conducted by SPSS (Version 22.0, SPSS, Inc., Chicago, IL, U.S.A.).

RESULTS

Reliability statistics are presented in Table 1. ICCs were moderate-excellent (0.636–0.783). The three insole conditions in the APSI, MLSI, VSI, and DPSI, indicate a good agreement.

Table 1: ICC and SEM of the three insole conditions in MLSI, APSI, VSI, and DPSI

Variables	ICC			SEM		
	no	soft	rigid	no	soft	rigid
MLSI	0.636	0.650	0.695	0.008	0.007	0.007
APSI	0.734	0.631	0.664	0.013	0.010	0.014
VSI	0.757	0.640	0.742	0.039	0.033	0.040
DPSI	0.783	0.658	0.742	0.040	0.034	0.040

Note: ICC represents Intraclass Correlation Coefficient; SEM represents Standard Error of the Mean. MLSI: Medial-lateral Stability Index; APSI: Anterior-posterior Stability Index; VSI: Vertical Stability Index; DPSI: Dynamic Postural Stability Index.

Results from the ANOVA indicated a significant insole effect in MLSI ($F_{2,38}$=5.106, p = 0.011, η^2 = 0.221). LSD post-hoc pairwise tests revealed that MLSI was significantly smaller in the soft insole and rigid insole condition compared to no insole condition ($p < 0.05$). However, there were no significant differences in APSI, VSI, and DPSI among the three insole conditions (Fig.2).

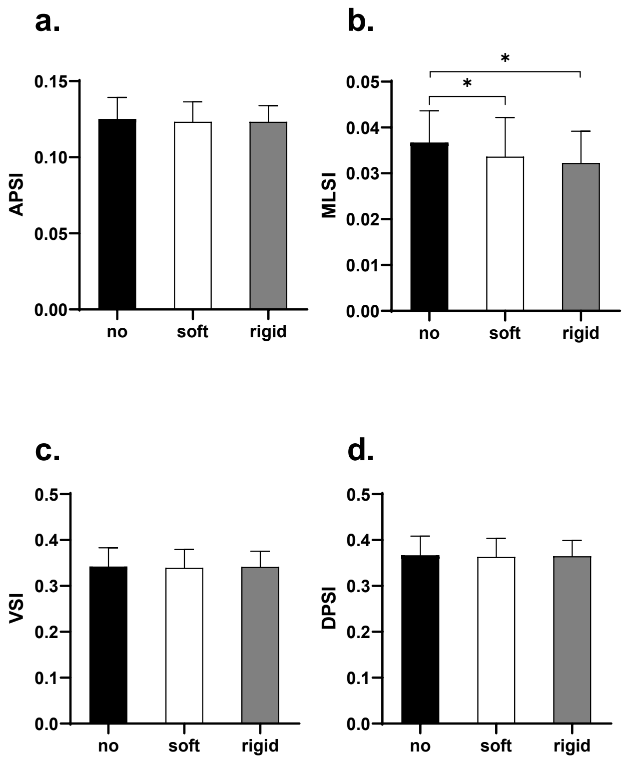

Figure 2. Dynamic stability variables in the no-, soft-, and rigid insole conditions, a) anterior-posterior stability index (APSI); b) medial-lateral stability index (MLSI); c) vertical stability index (VSI) and d) dynamic postural stability index (DPSI); Error bars are standard deviation; * indicates a significant difference between the two conditions; n = 20 in each case

As shown in Figure 3, a significant insole effect was observed in CA ($F_{2,38}$=10.988, p <0.0001, η^2 = 0.366) in the MF region. Post-hoc comparisons showed that the CA was significantly lower in the no insole condition compared to the soft- and rigid insole conditions in the MF region ($p < 0.05$). However, no significant differences in CA were observed in the forefoot and rearfoot regions among the three insole conditions ($F_{2,38}$=1.167, p = 0.322, η^2 = 0.058; $F_{2,38}$=1.187, p = 0.316, η^2 = 0.059).

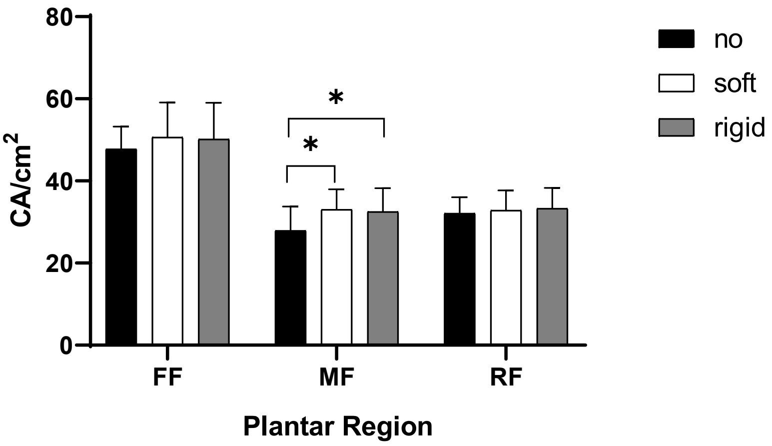

Figure 3. Contact area in the no-, soft-, and rigid insole conditions, CA: contact area; FF: forefoot; MF: midfoot; RF: rearfoot; Error bars are standard deviation; * indicates a significant difference between the two conditions; n = 20 in each case.

DISCUSSION

The purpose of this study was to determine whether insole hardness affects dynamic stability during single-leg jump landings. Results partially supported our first hypothesis that a soft or rigid insole would enhance dynamic postural stability of basketball athletes in medial-lateral directions compared to no insole condition. However, the second hypothesis that dynamic postural stability of basketball athletes was improved with insole hardness increasing was not supported.

Results of our study support the first hypothesis. Results showed that MLSI was significantly lower in the soft insole and rigid insole conditions for jump landing basketball players than the no insole condition. These results can be attributed to several reasons. First, some research found that stability improves due to increased midfoot contact area while wearing a full arch support insole [19], which is consistent with our study (midfoot contact was significantly lower without insole than insole conditions). Second, the support of the insole also enhanced stability. Some studies suggested that the arch support of the insole supported the medial midfoot, limited foot motions in medial-lateral directions [19, 20]. Finally, the contact areas between foot sole and shoe insole were linked to the facilitation of a neutral ankle position. Adjusting the ankle position by the insole was thought to balance the muscles and structures around the ankle joints, facilitated changes in the coronal and sagittal planes of the feet, impacted the surrounding tissues, created aberrant foot motion [21].

Secondly, an insole may assist in maintaining stability of basketball athlete by providing improved sensory feedback from the foot [16, 22]. It has been established that activating the plantar proprioceptive mechanoreceptors is critical for athletes to maintain balance and dynamic stability during sports-related movements. Previous studies have shown that textured insoles can improve the balance control ability of the human body by increasing the stimulation to the foot sole [9, 23]. These results indicated that more sensory input might be caused by the increased contact area between the foot sole and shoe insole when wearing shoes with insoles. It indicated that the insole would improve the dynamic postural stability of basketball athletes in the medial-lateral direction compared to the no insole condition.

The results of our study rejected the second hypothesis. No significant differences were observed in all three insole conditions in MLSI, APSI, VSI, and DPSI. However, Xingda Qu’s study [13] showed that rigid insoles were better than soft insoles in DPSI for older adults, suggesting that rigid insoles could improve DPSI. It was inconsistent with our study, which may be due to differences in the age of the participants and experimental tasks. Older subjects were in a declining stage of proprioception and may have been more responsive to insole stimulation [24, 25]. Compared with older adults, young adults have better balance adjustment ability. The change of insole hardness was not enough to change the dynamic stability of young adults in the landing and other challenging tasks [26].

It is critical to consider some of the limitations in this study when interpreting our findings. One limitation of this study was that only the effect of insole hardness on dynamic stability was investigated; future research should focus on the effects of insole materials, shape, and thickness on postural control of athletes when they perform high-risk tasks. In addition, we did not conduct any direct sensory or motor function measurements. As a result, this study cannot provide direct insight into the mechanisms underlying the benefits of insole intervention in postural stability.

CONCLUSIONS

Results of our study indicated that the dynamic stability of basketball athletes was increased by the shoe insoles in the medial-lateral direction during jump landing manoeuvres. However, a rigid insole did not contribute to the increased dynamic stability of basketball athletes during jump landing manoeuvres. Further studies should consider the insole material, arch support height, and insole thickness for better dynamic postural control in landing-related sports.

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PLANTAR FOOTPRINTS AND 3D FOOT SHAPE DIGITAL ANALYSIS FOR OVERWEIGHT TEENAGER – ONE CASE STUDY

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PLANTAR FOOTPRINTS AND 3D FOOT SHAPE DIGITAL ANALYSIS FOR OVERWEIGHT TEENAGER – ONE CASE STUDY

ABSTRACT. Nowadays, one of the most critical health problems among young people is obesity. Because teenagers are still in the growing process, the foot shape and plantar footprints are very important to be analysed and potential problems to be identified. Young adulthood is a risky period for the development of obesity. This study aims to analyse the plantar footprints, the biomechanical parameters obtained through plantar pressure measurements, and the 3D shape of the foot and anthropometrical parameters obtained from scanning. By comparing the results, both feet have been demonstrated to be high arched, as well as high pressures were identified and differences from left to the right foot. With these results, prophylactic footwear and components can be designed, adapted to the subject's feet.
KEY WORDS: plantar pressure, Body Mass Index, anthropometrical measurements

ANALIZA DIGITALĂ A AMPRENTELOR PLANTARE ȘI A FORMEI 3D A PICIORULUI PENTRU ADOLESCENTUL SUPRAPONDERAL – STUDIU DE CAZ

REZUMAT. În zilele noastre, una dintre problemele critice de sănătate în rândul tinerilor este obezitatea. Deoarece adolescenții sunt încă în proces de creștere, forma piciorului și amprentele plantare sunt foarte importante pentru a fi analizate și eventualele probleme de identificat. Acest studiu își propune să analizeze amprentele plantare, parametrii biomecanici obținuți prin măsurători ale presiunilor plantare, forma 3D a piciorului și parametrii antropometrici obținuți în urma scanării. Prin compararea rezultatelor, s-a demonstrat că ambele picioare sunt scobite, s-au înregistrat presiuni mari și diferențe de la piciorul stâng la cel drept. Folosind aceste rezultate, pot fi proiectate modele de încălțăminte și componente profilactice, adaptate la picioarele subiectului.
CUVINTE CHEIE: presiune plantară, indicele de masă corporală, măsurători antropometrice

L'ANALYSE NUMÉRIQUE DES EMPREINTES PLANTAIRES ET DE LA FORME 3D DU PIED POUR L'ADOLESCENT EN SURPOIDS – ÉTUDE DE CAS

RÉSUMÉ. De nos jours, l'un des problèmes de santé les plus critiques chez les jeunes est l'obésité. Comme les adolescents grandissent encore, la forme du pied et les empreintes plantaires sont très importantes pour analyser et identifier d'éventuels problèmes. Cette étude vise à analyser les empreintes, les paramètres biomécaniques obtenus en mesurant les pressions plantaires, la forme 3D du pied et les paramètres anthropométriques obtenus après le balayage. En comparant les résultats, il a été montré que les deux pieds sont creux, qu'il y a des pressions élevées et des différences du pied gauche au pied droit. A partir de ces résultats, des modèles de chaussures et des composants prophylactiques peuvent être conçus, adaptés aux pieds du sujet.
MOTS CLÉS : pression plantaire, indice de masse corporelle, mesures anthropométriques

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INTRODUCTION

Teenagers and child obesity have increased considerably in recent years. Around 12.7 million, or 17 percent of adolescents and children are overweight or obese. Obesity is one of the easiest medical issues to recognize but most difficult to treat. An increased weight gain due to poor diet and lack of exercise is responsible for more than 300,000 deaths each year. One way to manage children's and adolescents' obesity is to include the increase of physical activity (for example walking) and have a more active lifestyle, eating meals as a family instead of while watching television or at the computer [1-3].

Authorities reported that, for children and adolescents aged 2-19 years, in 2017-2018 [4]:

• The prevalence of obesity was 19.3% and affected about 14.4 million children and adolescents.

• Obesity prevalence was 21.2% among 12 to 19-year-olds. Childhood obesity is also more common among certain populations.

• Obesity prevalence was 16.1% among non-Hispanic white children.

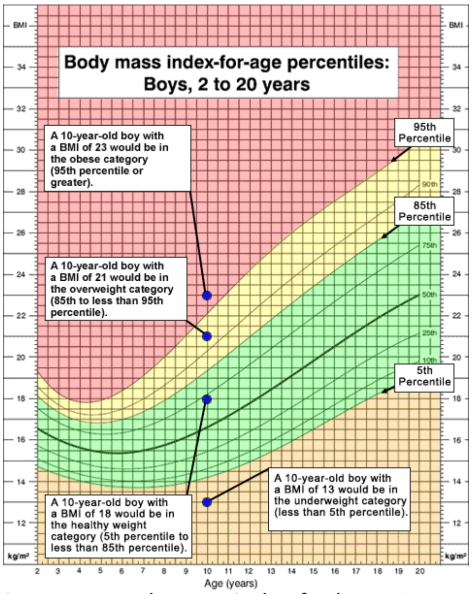

Figure 1.a. Body mass index for boys. Source: https://www.cdc.gov/healthyweight/assessing/bmi/childrens_bmi/about_childrens_bmi.html

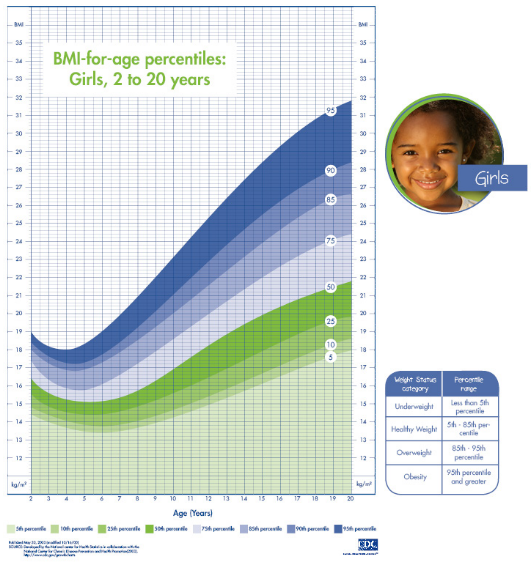

Figure 1.b. Body mass index for girls. Source: https://www.obesityaction.org/get-educated/understanding-childhood-obesity/what-is-childhood-obesity/girls-bmi-for-age-percentile-chart/

Based on probabilistic models, it is highly likely that overweight and obese adolescents suffer from obesity and other related illnesses – such as diabetes, orthopaedic (flat, high arched, or Hallux-Valgus feet), and psychological problems [5, 6]. Functional and structural limitations resulting from the additional load on the locomotor system by excess fat, resulting in wrong mechanics of movements [7, 8].

In a study undertaken by Jiménez-Ormeño, E. *et al.*, it is demonstrated that excess weight affects the feet structure of children. There are changes which show that the foot of overweight and obese children follows a distinct growth pattern, different than children with a normal-weight. Using those results, the footwear manufacturers can design and produce shoes for children taking into consideration their age and weight [9].

EXPERIMENTAL

Materials and Methods

The BMI of a child tells us if their weight is appropriate for their height. Instead of using the BMI categories used for adults, a child's BMI is given as a percentile [9]. Because children are constantly growing until around the age of 18, their age and whether they are a boy or girl is also used to work out their BMI percentile. A small change in weight or a few months' difference in age can change the percentile score. The BMI calculator works out if a child or young person is:

- underweight: on the 2nd percentile or below
- healthy weight: between the 3rd and 91st percentile
- overweight: 91st percentile or above
- very overweight: 98th percentile or above

Our subject has recorded a value of 99th percentile, meaning that he is VERY OVERWEIGHT.

Scanning the Foot

All experimental protocols were approved by a named institutional review board. The subject has been informed and consented to participation in the study. All methods were carried out following relevant guidelines and regulations.

The subject (9-year-old, male) was accompanied by a parent during testing, the parent has signed a consent form. He has been previously diagnosed with over-pronation. Several initial stages of structural modification related to his condition have been identified, in this case, especially in the rearfoot area.

The subject's foot is scanned by using a 3D foot scanning system; namely the INFOOT USB Standard Model IFU-S-01. INFOOT scans a foot and positions the anatomical landmarks, which are used to measure automatically/calculate up to 20 measuring items. The subject stands with one barefoot inside the scanner and one foot outside the scanner, and the entire mass of the subject is equally distributed on both feet [11, 12].

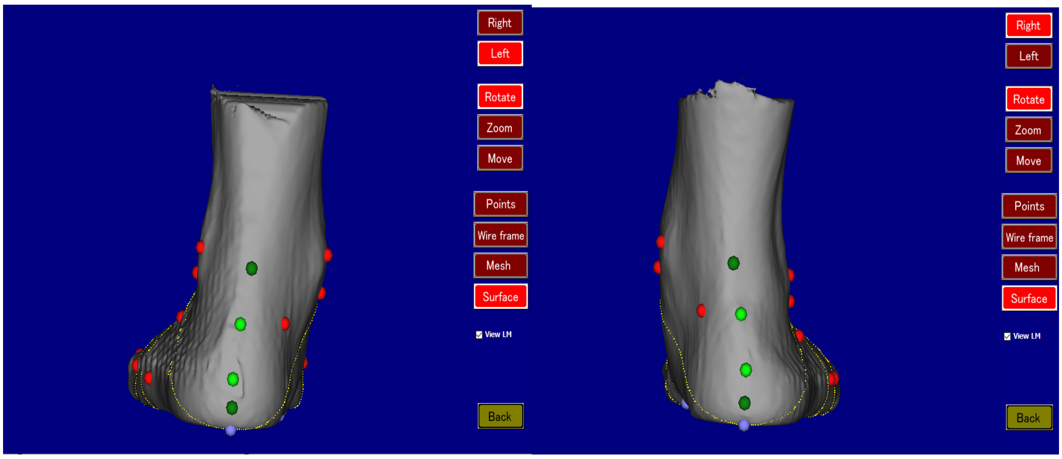

Figure 2. 3D Shape of the scanned feet

The scanned foot data can be used for foot morphological analysis, footwear/last selection, and also for designing new lasts or re-designing existing ones, especially in case of customized footwear.

It can be seen from Figure 2 that the feet are over-pronated, and the left foot is more pronated than the right one. These images show valgus feet, with a postural deformity characterized by exaggerated dorsiflexion of the foot.

Plantar Pressures

The RSScan 2D plate of 0.5 m and its associated software, namely Footscan Gait Scientific, have been used. The experimental task that was followed up comprises measurements in:

- Statics – the subject was required to find his balance on the pressure plate having his weight equally distributed on both feet. Then a capture of the plantar pressure has been taken.
- Dynamics – the subject was required to walk, passing on the pressure plate with the left foot. One capture in dynamics has been taken. The subject repeats this movement stepping with the right foot on the plate. Three measurements on each foot have been taken to obtain reliable and comparable sets of data.

RESULTS AND DISCUSSIONS

Anthropometrical Measurements

Accurate positioning of the anatomical points influences the value of anthropometric parameters. For the hereby-presented study case, the mapping of the anatomical points suggested by the scanner's producer – INFOOT was used [13]. The landmarks are automatically given by the software in a few seconds. Because several problems and structural modifications against the normal foot have been identified for this case, each anatomical point is checked, and it is moved (if necessary) in its right position. After correct positioning of anatomical points, the anthropometrical chart is automatically generated, the results can be seen in figure 3.

Dimension	Left	Right
Foot length	230.6 mm	229.6 mm
Ball Girth circumference	220.4 mm	216.2 mm
Foot breadth	87.4 mm	83.2 mm
Instep circumference	219.8 mm	217.6 mm
Heel breadth	60.7 mm	61.0 mm
Instep length	168.3 mm	155.6 mm
Fibular Instep length	138.8 mm	134.6 mm
Height of Top of Ball Girth	41.9 mm	44.9 mm
Height of Instep	57.8 mm	58.6 mm
Toe #1 angle	1.3 °	0.4 °
Toe #5 angle	0.7 °	2.7 °
Height of Toe #1 joint	23.3 mm	24.6 mm
Height of Toe #5 joint	18.3 mm	19.2 mm
Height of navicular	39.1 mm	33.1 mm
Height of Sphyrion fibulare	59.1 mm	48.1 mm
Height of sphyrion	52.6 mm	58.6 mm
Height of the most lateral Point of lateral malleolus	69.6 mm	58.6 mm
Height of the most medial Point of medial malleolus	68.1 mm	69.1 mm
Angle of heel bone	7.5 °	8.2 °
Heel Girth circumference	320.9 mm	299.9 mm
Horizontal Ankle circumference	268.7 mm	248.6 mm
Calf circumference	---.- mm	---.- mm
Foot size	23.0 C	23.0 C

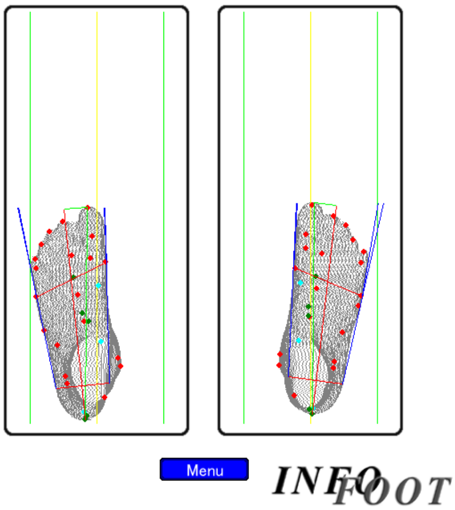

Figure 3. Feet anthropometrical measurements

Plantar Pressure Measurements

The static printout (figure 4.a.) gives the first information on the pressure distribution over the plantar area and the shape of the foot. For the investigated subject, both feet are high arched, with a peak of pressure under the heel. The contact areas between foot and ground are on the heel and only in a very small forepart area.

Figure 4.b. shows the distribution of pressures during all phases of rolling the feet on the ground. In this case, the high pressure is still on the heel, but the plantar shape is closer to normal, not so much high arched as in static position.

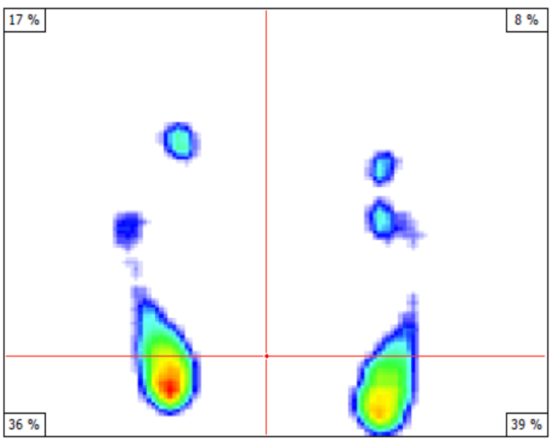

Figure 4.a. Static printout

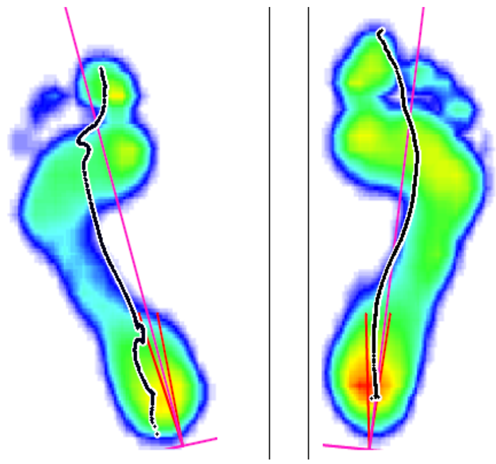

Figure 4.b. Dynamic printout

The gait cycle can be divided into three main stages: the first contact with the surface (impact), the stance stage when the entire foot is in contact with the ground, and the propulsion stage when the foot is pushing off the ground. Five phases of the gait cycle are presented for the left foot and 5 phases for the right foot (figure 5). For the herby study case, the left step time is 511 ms and the right step time is 575 ms, both values being under the average step time of 900-990 ms reported in other studies.

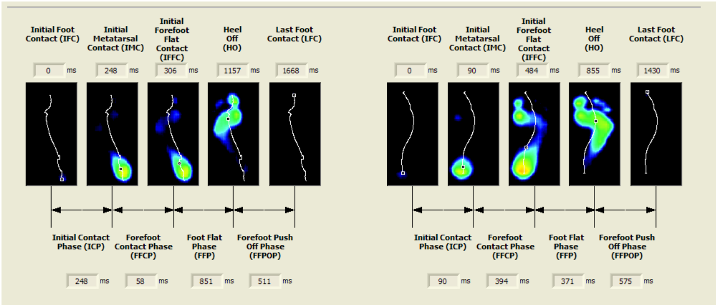

Figure 5. Gait cycle

The Footscan software gives the pressure graphs depending on the foot areas (figure 6). Therefore, the foot is divided into 10 areas (toe 1, toe 2 to 5, metatarsal 1 to 5, medium foot, medial heel, and lateral heel), each of them being differently coloured. The same legend of colours is kept for pressure graphs, to easily recognize how the pressure varies for each area of the foot.

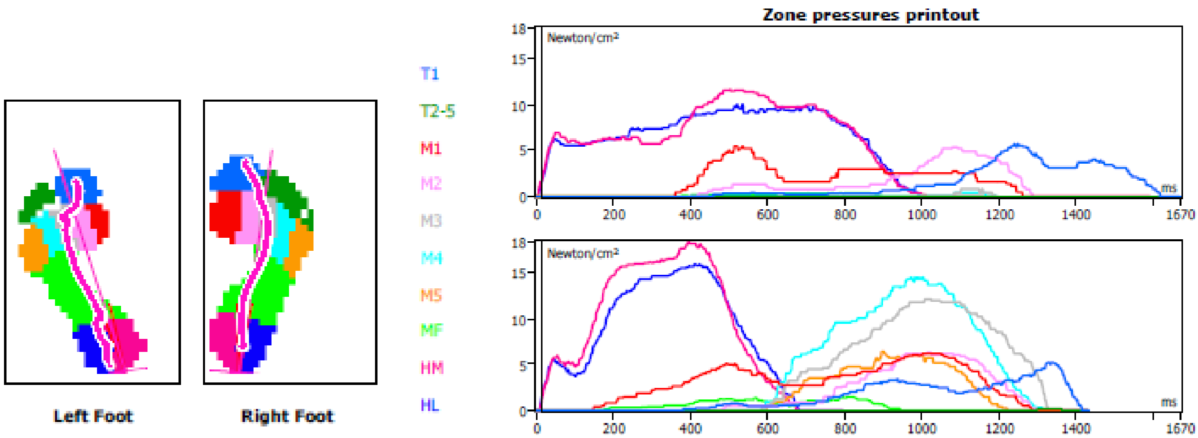

Figure 6. Pressure graphs depending on the foot areas – left foot and right foot

Each pressure graph can be divided into 3 phases: heel contact, foot contact, and push off. Two pressure peaks are visible on each graph: one during the heel contact stage and one during the pushing off stage. For a normal gait pattern, these two peaks have appropriate values.

The maximum pressures, impulse, contact, and time are extracted for both subject's feet. The values are analysed using a T-test to identify if there are significant differences between the right and left foot.

Table 1: Biomechanical parameters on different areas of the foot and T-Test

	Start Time	End Time	% Contact	Max P	Impulse	Contact area
Left	ms	ms	%	N/cm²	Ns/cm²	cm²
Toe 1	459	1619.5	69	5.7	2.1	12.4
Toe 2-5	2	1668	100	0	0	7.1
Meta 1	360.4	1263.6	54	5.4	2.3	5.6
Meta 2	420.7	1289.3	52	5.3	1.8	8.6
Meta 3	1082.5	1185.5	6	0.8	0.1	6.4
Meta 4	1082.5	1167.5	5	0.4	0	6.8
Meta 5	2	1668	100	0	0	9
Midfoot	403.1	889.8	29	0.3	0.1	29.2
Heel Medial	5.1	1012.9	60	11.6	7.1	13.9
Heel Lateral	6.5	1001.1	60	10	6.9	12
Right	ms	ms	%	N/cm²	Ns/cm²	cm²
Toe 1	381	1417.5	72	5.2	2.1	12.8
Toe 2-5	1299	1365	5	0.2	0	12.8
Meta 1	148.5	1287.4	79	6.2	4	12
Meta 2	482.8	1299.2	57	6.3	2.5	10.1
Meta 3	584.6	1329.6	52	12.1	5.5	8.2
Meta 4	584.6	1315.4	51	14.4	6	7.9
Meta 5	596.7	1223.3	44	6.4	2.3	9.4
Midfoot	176.3	946.8	54	1.5	0.6	30
Heel Medial	10.4	676.9	46	18.3	7	13.9
Heel Lateral	10.3	683.1	47	15.9	6.3	12
T-TEST	0.398828	0.05769	0.42365025	0.0079721	0.029962	0.0178
	>0.05	>0.05	>0.05	<0.05	<0.05	<0.05

The anthropometrical parameters are extracted for both subject's feet. The values are analysed using a T-test to identify if there are significant differences between the right and left foot.

Table 2: Anthropometrical parameters of the foot and T-Test

Dimensions	Left	Right
1. Foot Length	230.6 mm	229.6 mm
2. Ball Girth	220.4 mm	216.2 mm
3. Foot breadth	87.4 mm	83.2 mm
4. Instep circumference	219.8 mm	217.6 mm
5. Heel breadth	60.7 mm	61.0 mm
6. Instep length	168.3 mm	155.6 mm
7. Fibular instep length	138.8 mm	134.6 mm
8. Height of Top Ball Girth	41.9 mm	44.9 mm
9. Height of Instep	57.8 mm	58.6 mm
10. Toe 1 angle	1.30	0.40
11. Toe 5 angle	0.70	2.70
12. Height of toe 1 joint	23.3 mm	24.6 mm
13. Height of toe 5 joint	18.3 mm	19.2 mm
14. Height of navicular	39.1 mm	33.1 mm
15. Height of Sphyrion fibulare	59.1 mm	48.1 mm
16. Height of Sphyrion	52.6 mm	58.6 mm
17. Height of lateral malleolus	69.6 mm	58.6 mm
18. Height of medial malleolus	68.1 mm	69.1 mm
19. Angle heel bone	7.50	8.20
20. Hell Girth	320.9 mm	248.6 mm
21. Foot size (French)	23	23

T-TEST: p = 0.087> 0.05

Based on the human body symmetry, the initial hypothesis is that there are no significant differences between left and right foot. For testing this hypothesis, a T-Test is conducted for a pre-set probabilistic limit of p=0.05. If the result of the T-Test is inferior to p, then the hypothesis is rejected.

For the biomechanical analysis, the calculated value for Student test is lower than p=0.05 for maximum pressure, impulse, and contact area. Thus, the initial hypothesis is rejected and there are significant differences between left and right foot.

For the anthropometrical analysis, the calculated value for Student test is 0.087, which is lower than p=0.05. Thus, the initial hypothesis is accepted and there are no significant differences between left and right foot.

Even if the investigated subject doesn't have visible differences on anthropometrical values, the difference in the position of the foot (seen in 3D), the pressure distribution between left and right foot in statics, the analysis of values in dynamics demonstrates that there are significant statistical differences and prophylactic footwear and orthoses are recommended.

CONCLUSIONS

By comparing the results, both feet have been demonstrated to be high arched, as well as high pressures were identified. For orthopaedists, it could be a very good example of establishing the typology of the foot to suggest special devices to be introduced inside the shoe or customized soles and insoles. A T-Test is conducted for anthropometrical and biomechanical parameters. The result of this test is that there are significant differences between the pressures of the two feet, and the need to design separately the bottom components. An analysis of gait time was made, the result being a normal distribution on each area of the foot.

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RESEARCH ON FOOT ANTHROPOMETRY OF MEN WITH DIABETES IN VIETNAM

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RESEARCH ON FOOT ANTHROPOMETRY OF MEN WITH DIABETES IN VIETNAM

ABSTRACT. Diabetes often causes foot complications, inducing diabetic patients to use therapy shoes or custom-made shoes designed on the basis of anthropometric characteristics of their feet to ensure a good fitting. Wearing poorly fitted shoes contributes to the development of foot ulcer sites. This paper presents the results of foot anthropometric research, developing a foot size system for men with diabetes in Vietnam in order to develop pressure-offloading footwear. The foot data of 212 men with type-2 diabetes aged 44 to 75 years were collected during this study. Foot photography and patient interviews about foot complications were also conducted by research assistants. The results show that the average disease duration of the surveyed patients was statistically calculated as 6.8 ± 4.3 years. The patients from 50 to 70 years old accounted for up to 86.8% of all interviewees. In all participants, the patients with foot pain and swelling of metatarsal joints accounted for 19.8%, foot ulcers accounted for 6.4%, dry feet, cracked skin, and calluses almost equally accounted for 12%. Most of the feet are slightly deformed mainly in the metatarsal joint area and no patient had a leg amputation. The patients suffering from two types of foot injuries account for more than 43.1%. Interestingly, the ball width and circumference of the patient's foot are 4.5 mm and 6.5 mm larger than that of a healthy man's foot, respectively; whereas, the mid-foot height is 3.7 mm lower. From the collected data and statistic figures, the patient foot sizing system has been developed including 5 sizes by length (231.5, 238.0, 244.5, 251.0, 257.5 mm), and each size by length is divided into 3 sizes by width. Our categorizing system meets more than 81.5% of the shoe size needed by men with diabetes in Vietnam.

KEY WORDS: diabetic foot, foot anthropometry, foot ulcers

CERCETĂRI PRIVIND ANTROPOMETRIA PICIORULUI LA BĂRBAȚII CU DIABET DIN VIETNAM

REZUMAT. Diabetul provoacă adesea complicații ale picioarelor, determinând pacienții diabetici să folosească încălțăminte terapeutică sau încălțăminte personalizată concepută pe baza caracteristicilor antropometrice ale picioarelor pentru a le asigura o potrivire bună. Purtarea pantofilor nepotriviți contribuie la dezvoltarea zonelor ulceroase ale piciorului. Această lucrare prezintă rezultatele cercetării antropometrice ale piciorului, dezvoltând un sistem de mărime a piciorului pentru bărbații cu diabet din Vietnam, în scopul dezvoltării unui tip de încălțăminte care să atenueze presiunea. În acest studiu s-au colectat datele a 212 bărbați cu diabet zaharat de tip 2 cu vârsta cuprinsă între 44 și 75 de ani. Fotografiile picioarelor și interviurile cu pacienții despre complicațiile la nivelul picioarelor au fost, de asemenea, efectuate de asistenți de cercetare. Rezultatele arată că durata medie a bolii la pacienții chestionați a fost calculată statistic ca fiind de 6,8 ± 4,3 ani. Pacienții cu vârsta cuprinsă între 50 și 70 de ani au reprezentat până la 86,8% din toți cei intervievați. Din toți participanții, pacienții cu dureri de picior și articulații metatarsiene umflate au reprezentat 19,8%, ulcerele piciorului au reprezentat 6,4%, picioarele uscate, pielea crăpată și calusurile au reprezentat aproape în egală măsură 12%. Majoritatea picioarelor sunt ușor deformate în principal în zona articulației metatarsiene și niciun pacient nu a avut amputație de picior. Pacienții care suferă de două tipuri de leziuni ale picioarelor reprezintă mai mult de 43,1%. Interesant este că lățimea și circumferința zonei metatarso-falangiene a pacientului sunt cu 4,5 mm și, respectiv, 6,5 mm mai mari decât cea a piciorului unui bărbat sănătos; în timp ce înălțimea în zona mediană a piciorului este cu 3,7 mm mai mică. Pornind de la datele colectate și cifrele statistice, s-a dezvoltat sistemul de dimensionare a piciorului pacientului incluzând 5 dimensiuni după lungime (231,5, 238,0, 244,5, 251,0, 257,5 mm), iar fiecare dimensiune după lungime este împărțită în 3 mărimi după lățime. Sistemul nostru de clasificare acoperă mai mult de 81,5% din mărimea pantofilor necesară bărbaților cu diabet din Vietnam.

CUVINTE CHEIE: picior diabetic, antropometria piciorului, ulcerul piciorului

RECHERCHE SUR L'ANTHROPOMÉTRIE DU PIED DES HOMMES DIABÉTIQUES AU VIETNAM

RÉSUMÉ. Le diabète entraîne souvent des complications du pied, incitant les patients diabétiques à utiliser des chaussures thérapeutiques ou des chaussures sur mesure conçues sur la base des caractéristiques anthropométriques de leurs pieds pour assurer un bon ajustement. Le port de chaussures mal ajustées contribue au développement de sites d'ulcères du pied. Cet article présente les résultats de la recherche anthropométrique du pied, développant un système de taille de pied pour les hommes diabétiques au Vietnam afin de développer des chaussures de décharge de pression. Les données des pieds de 212 hommes atteints de diabète de type 2 âgés de 44 à 75 ans ont été recueillies au cours de cette étude. Des photographies de pieds et des entretiens avec des patients sur les complications du pied ont également été réalisés par des assistants de recherche. Les résultats montrent que la durée moyenne de la maladie des patients interrogés a été calculée statistiquement à 6,8 ± 4,3 ans. Les patients de 50 à 70 ans représentaient jusqu'à 86,8 % de toutes les personnes interrogées. Chez tous les participants, les patients souffrant de douleurs aux pieds et de gonflement des articulations métatarsiennes représentaient 19,8 %, les ulcères du pied représentaient 6,4 %, les pieds secs, la peau craquelée et les callosités représentaient presque également 12 %. La plupart des pieds sont légèrement déformés principalement au niveau de l'articulation métatarsienne et aucun patient n'a subi d'amputation de pied. Les patients souffrant de deux types de blessures aux pieds représentent plus de 43,1 %. Fait intéressant, la largeur et la circonférence de la balle du pied du patient sont supérieures, de 4,5 mm et 6,5 mm, respectivement, à celles du pied d'un homme en bonne santé ; tandis que la hauteur du milieu du pied est inférieure, de 3,7 mm. À partir des données collectées et des chiffres statistiques, le système de dimensionnement du pied du patient a été développé, comprenant 5 tailles par longueur (231,5, 238,0, 244,5, 251,0, 257,5 mm), et chaque taille par longueur est divisée en 3 tailles par largeur. Notre système de catégorisation répond à plus de 81,5 % de la pointure nécessaire aux hommes atteints de diabète au Vietnam.

MOTS CLÉS : pied diabétique, anthropométrie du pied, ulcères du pied

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INTRODUCTION

Diabetes is a disease occurring when blood glucose – hyperglycemia – raises to high levels or stays unstable. Foot injury is a common complication ensuing diabetes, including foot pain, skin changes, calluses, foot deformities, ulcers, and amputation [1-3]. Muscle atrophy in the diabetic foot causes convex and concave muscle surface, increasing the pressure when walking, this is the major effect leading to foot ulcers [4]. The microvascular and peripheral nerves of the damaged foot inflict loss of sensation. Foot complications lead to changes in the shape and parameters of the patient's feet. In addition, the repetitive pressure of body weight on the feet, while walking, raises amputation risk.

There are many factors that affect diabetic foot complications such as duration of illness, the severity of disease, age, gender, living and working environmental conditions, foot care, use of footwear, and so on [2, 3]. Among the various types of foot lesions, foot ulcers are the most common problem in diabetic feet that fifteen percent of diabetic patients worldwide may develop. Previously published studies have found that the majority of ulcers originate from the plantar areas of the feet. Most foot ulcers are found in the plantar area due to peak plantar pressure, abnormal foot shape, toe deformity, and insensate foot. They usually develop under the tips of the metatarsal joints and in the toes [1, 5-8]. Studies on the foot injury of diabetic patients in Vietnam specifically found that the rate of foot ulceration ranged from 28.9% to 43.62%. And the ulcers also grow mainly on the forepart of the foot plantar. One of the main causes of foot ulcers is that patients do not use comfortable and appropriate footwear, in many cases they do not use footwear in the least [9-12].

Adequate footwear, distributing pressures across the foot to lessen stress at targeted regions, can play an important role in preventing the risk of foot ulceration. Therapy shoes and custom-made shoes are designed according to the patient's foot anthropometric characteristics to relieve mechanical pressure. The differences in the parameters of the right foot and the left foot have been studied to be insignificant [13-16]. Several studies have compared diabetic foot parameters with those of healthy human feet. Their results found that first of all, the foot length of diabetic patients did not differ from that of healthy subjects [14-16], or no more than 3 mm deviation [13]. Their width parameters may be wider [13, 15-17] or equal in other cases [14]. Finally, foot circumference is mostly larger than that of a healthy person's foot [12-16]. Interestingly, main divergences depend significantly on age group, sex, and body mass indexes [18]. Therefore, it is necessary to study the foot anthropometry of patients with diabetes regarding the abovementioned factors before manufacturing footwear to prevent foot ulceration [18].

Anthropometric characteristics of human feet are affected by many factors such as race, gender, age, living conditions, and geographical inhabitation [19]. Meanwhile, there have been not so many studies conducted respecting foot anthropometry in diabetic patients for the purpose of designing and fabricating footwear in Vietnam. Currently, in Vietnam there are no therapeutic shoes or customized shoes to reduce the incidence of neuropathic ulcers in high-risk diabetic patients. Patients, therefore, employ casual footwear which does not fit the characteristics of the diabetic feet, exposing them to indirect damage as well as irritation. And this is also one of the reasons increasing the rate of foot ulcers in patients caused by plantar and dorsal surface stress [9-12]. Recently, scientists have begun to study the sex factor in designing shoes for male and female diabetic patients, because varied sensory perceptions influence customized products [15, 16]. However, there have been no studies on foot anthropometry of Vietnamese males and females with diabetes, the basis for designing and manufacturing therapeutic shoes for patients.

This study focuses on evaluating anthropometric characteristics of the feet of diabetic males in Vietnam to construct a parameter system of the foot size. We used measuring instruments to collect foot data from 212 diabetic men with foot lesions photographed.

The patients were interviewed directly to clarify the history of foot complications. The foot anthropometric characteristics of the patients were evaluated by comparing their foot parameters with the same foot parameters of healthy men. Based on the collected data, a foot size system was built for the purpose of designing shoe shapes, providing therapeutic footwear for patients.

EXPERIMENTAL

Materials and Methods

Subjects

The subjects of this study are the feet of men with type 2 diabetes. They are usually examined and receive medication at the local health centers in Vietnam. This is a group of patients with low and moderate risk of foot ulcers. They should be able to use “Extra Depth Diabetic Shoes” or therapeutic shoes [20]. Some information about the studied diabetic patients is shown in Table 1.

Table 1: Some information about the studied diabetic patients

	Min	Max	Averaged ± SD
Age, year	44	75	59.1 ± 5.8
Body height, cm	153	180	164.5 ± 9.0
Weight, kg	44	91	60.4 ± 8.0
Disease duration, years	1	16	6.8 ± 4.3

Among the surveyed patients, by occupation, civil servants are 14.8%, workers are 15.8%, farmers are 49.6%, others are 19.7%.

Measurement Method

In this study, the direct measurement method [19] was used to measure the feet of diabetic patients. Feet are measured in the upright standing position, body weight evenly distributed on both feet. The distance between the two feet is 20 cm. Both patient feet were measured. The foot measuring device includes a soft narrow tape measure, a caliper with a 1 mm scale, a footprint device, and a camera. Measurement time is from 9 am to 11 am on weekdays. The anthropometric points on the foot and the way to measure the foot sizes are shown in figure 1 [19].

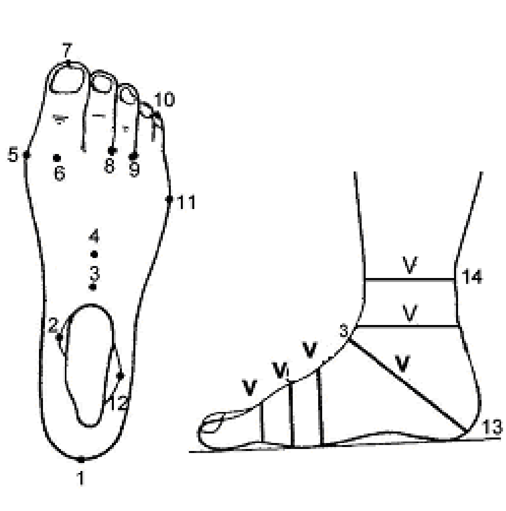


Figure 1. Foot anatomy points and foot measurements

1 – Pternion
2 – The most medial point of medial malleolus
3 – Junction point
4 – Top of instep point
5 – Metatarsale tibiale
6 – Top of ball girth point
7 – Tip of 1st toe
8 – Point between 2nd toe and 3rd toe
9 – Point between 3rd toe and 4th toe
10 – Tip of 5th toe
11 – Metatarsale fibulare
12 – The most lateral point of lateral malleolus
13 – Landing point
14 – Ankle point

Foot length and width parameters are determined by its contour (Figure 1 c):

Lf – Foot length: Distance from point 1 to point 7;

Lmb – Length to medial ball: Distance from point 1 to point 5;

Llb – Length to lateral ball: Distance from point 1 to point 11;

L5toe – Length to the end of 5th toe: Distance from point 1 to point 10;

Lla – Length to center of lateral ankle: Distance from point 1 to point 12;

Rmb – Width of medial ball: Distance from point 5 to point F;

Rlb – Width of lateral ball: Distance from point 11 to point M;

Rb – Width of ball: Distance from point 11 to point 5;

Rh – Width of heel: Measured at the widest part of the heel.

Vmb – Medial ball girth: Perimeter of cross-section measured through point 5;

Vlb – Lateral ball girth: Perimeter of cross-section measured through point 11;

Vb – Ball girth: Perimeter of cross-section measured through point 5 and point 11;

Vw – Waist girth: Perimeter of cross-section measured through point 4;

Vins – Instep girth: Perimeter of cross-section measured through point 3;

Vh – Heel (cross) girth: Perimeter of cross-section measured through points 3 and 13;

Va – Ankle girth: Perimeter of cross-section measured through point 14;

C1toe – Height at 1st toe: Measured in the middle of 1st toenail;

Cmb – Medial ball height- Height at point 6;

Cins – Instep height - Height to point 3;

Cla – Height at lateral ankle center: Height to point 12;

H – Longitudinal arch factor: Determined by footprint parameters (ratio of ig/zv) (see Fig. 1c) [19]:

H-value from 0 to 0.51: high arch feet;
H-value from 0.51 to 1.1: Normal foot;
H-value from 1.11 to 1.3: Low arched foot;
H-value from 1.31 to 1.5: Flat foot.

α – Angle of the big toe: determined by foot contour (see Fig. 1c).

In addition to measurements, lesions of the foot such as joint swelling, ulceration, edema have been recorded. The feet were also photographed. The research team talked to and interviewed the patients to get information about the history and progression of foot complications.

Data Processing

According to foot images and patient interview results, the extent and types of foot complications were evaluated. The maximum, minimum, and mean and standard deviation values of the left and right feet parameters are determined and compared. The values of the surveyed foot parameters were compared with those of healthy men's feet [21]. Regression equations and correlation coefficients between foot parameters, and foot parameters system were built [19].

The analysis of variance (ANOVA) was applied to confirm that there are no significant differences between the left and right foot of the study patients, as well as the difference between their feet parameters and that of the healthy men's feet. The calculated values are compared with p = 0.05 for a probability of 95% to determine if the results obtained are statistically significant. The values must be greater than p = 0.05 to confirm the null hypothesis.

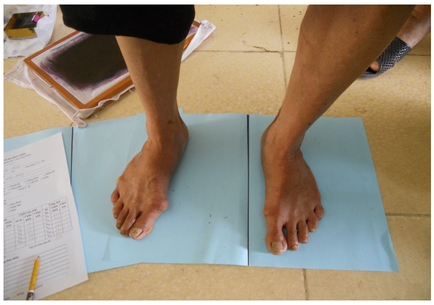
RESULTS AND DISCUSSIONS

Complication Characteristics of Diabetic Men's Feet

Observations recorded during the foot measurement of diabetic men showed that calluses were concentrated in the ball joints, toes, and ankles. The proportion of patients with swollen, slightly deformed medial ball joints accounted for 32.5%. Statistics of types of foot lesions in diabetic men are shown in Table 2.

Table 2: Types of foot lesions in diabetic men

Types of foot injuries	Ratio, %	Disease duration, years	Image of foot injury
Uncomplicated feet	33.6	3.64 ± 2.1	
Foot pain and ball swelling	19.8	3.90± 1.9	
Skin changes (dry, cracked skin)	12.0	4.1 ± 2.9	

Types of foot injuries	Ratio, %	Disease duration, years	Image of foot injury
Calloused feet	15.8	4,20 ± 3,0	
Deformed foot	12.5	5.10 ± 3.8	
Foot ulcers	6.4	6.21± 4.4	
Total	143.1		

The number of patients with unaffected feet accounted for nearly 33.6%, and 18.8% lower than female diabetic patients [12]. The feet of these patients were similar to those of healthy men. Feet with painful and swollen ball joints accounted for 19.8%, foot ulcers accounted for 6.4%, dry feet, cracked skin and foot callus are almost equal, accounting for about 12%. The degree of foot deformity of the patient is mild. The deformed position is mainly in the ball joint area. No patient had foot amputation, lost foot sensation. The extent of foot damage increases with the duration of the disease. The number of patients suffering from 2 types of foot injuries is relatively high, accounting for more than 43.1%, and 17.4% higher than female diabetic patients [12].

Main Foot Anthropometric Characteristics of the Studied Diabetic Man

The results of measurement data processing showed that there was no difference (p > 0.05) between the parameters of length, width, height, and circumference of the right and left feet of men with diabetes. This result is similar to that of female diabetic feet in Vietnam [16], as well as the results of published research [13-16].

Anthropometric features of the foot of diabetic men compared with normal foot size have been published [21] as shown in Table 3.

Table 3: The size of diabetic men's feet and normal men's feet

Foot size	Men's foot parameters, mm			*p* -value
	Diabetic patient	Healthy	Different	
Lf	244.3±8.8	245.0±10.7	-0.7	0.45
Lmb	179.6±7.8	175.7±9.4	3.9	0.123
Llb	159.2±7.4	156.2±9.2	3	0.015
L5toe	202.0±8.2	195.4±10.6	6.6	0.025
Rmb	99.7±7.2	95.6±4.9	4.1	0.002
Rlb	96.1±7.2	94.1±5.0	2	0.057
Rb	102.9±7.2	98.4±5.1	4.5	0.004
Rh	65.4±5.7	61.0±4.0	4.4	0.005
C1toe	19.8±2.4	19.1±2.2	0.7	0.105
Cmb	32.9±3.3	35.6±3.2	-2.7	0.052
Cins	53.4±5.1	57.1±5.3	-3.7	0.007
Cla	59.6±5.2	69.2±5.7	-9.6	0.008
Vmb	230.8±13.0	225.3±11.2	5.5	0.016
Vlb	235.0±12.4	230.6±11.5	4.4	0.028
Vb	241.0±13.5	234.8±11.9	6.2	0.019
Vw	235.2±12.5	231.6±11.6	3.6	0.048
Vins	245.1±12.9	240.3±12.1	4.8	0.031
Vh	318.8±17.0	315.6±15.8	3.2	0.086
Va	237.6±13.8	233.5±12.7	4.1	0.069
H	1.21±0.34	1.02±0.28	0.19	0.029
α	4.80 ± 6.3	2.50 ± 4.2	3.3	0.066

According to the data in Table 3, there was no difference in foot length of diabetic men and healthy men's feet. The foot width and girth of diabetic men are larger than that of healthy men. Specifically, the width of the ball joint is greater than 4.5 mm, the ball girth is greater than 6.2 mm. The standard deviation of the foot width sizes and girth of diabetic men is larger than that of healthy men. The cause may be due to complications of swollen ball joints in the feet of diabetic patients. In contrast, the foot height of diabetic men is smaller than that of healthy men. For example, the midfoot height is less than 3.7 mm. This is reasonable since compared with the healthy man's feet, the medial longitudinal arch of the diabetic man's feet is lower ($p<0.05$). In addition, this problem may be related to tissue atrophy in the plantar of the diabetic feet. This can also be the cause of the increase in their width parameters. There was no significant difference ($p>0.05$) between the hallux angle of the patient's foot and that of the healthy man's foot.

Building the Foot Size System for Diabetic Men

Foot length is often the dominant parameter for building a length size system. The ball girth is usually the dominant parameter for sizing by width. For the studied diabetic men's feet, the measured and theoretical (normal distribution) curves of the length and ball girth were quite close to each other (Figures 2 and 3). The calculated values of c^2 according to the foot length and ball girth, respectively 5.2 and 9.0, are smaller than the value of c^2 in the table with a probability of 95%. This confirms that these parameters are suitable as the dominant for the building of the foot size system [19].

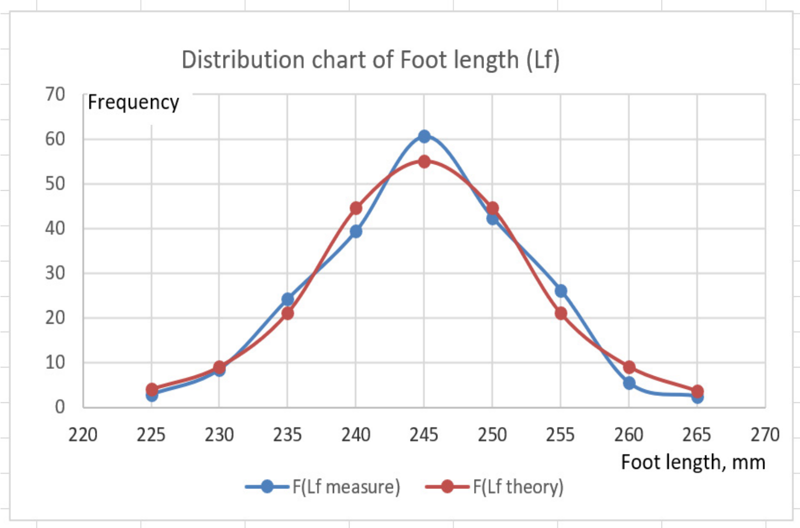


Figure 2. Theoretical and practical distribution charts by foot length

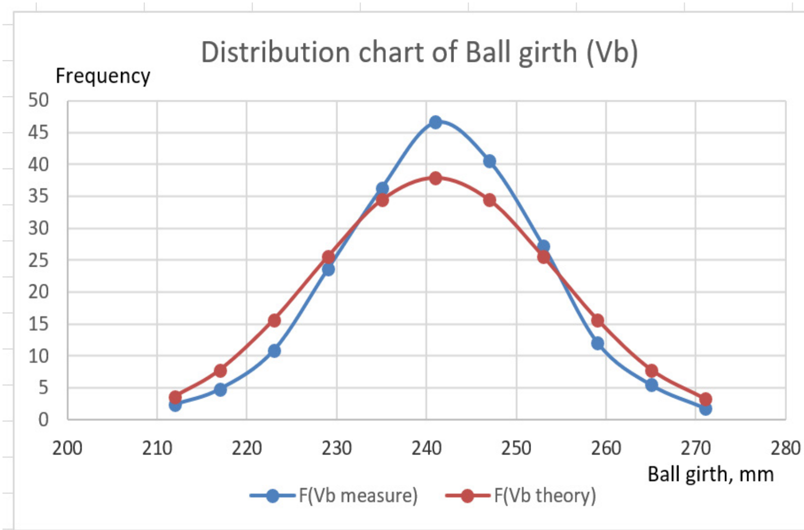


Figure 3. Theoretical and practical distribution charts by ball girth

According to the measured data, regression equations and correlation coefficient r have been built. They show the relationship between the patient's foot remaining parameters and the dominant parameters (Table 4).

Table 4: Regression equations of diabetic men's feet

N^o	Foot parameters	Regression	r	*p*
1	Lmb	Lkt = 0.736 Lf	0.85	< 0.005
2	Llb	Lkn = 0.652Lf	0.83	< 0.005
3	L5toe	L5toe = 0.828Lf	0.87	< 0.005
4	Lla	Lla = 0.228Lf	0.48	< 0.050
5	Rmb	Rmb = 0.413Vb	0.65	< 0.005
6	Rlb	Rlb = 0.399Vb	0.73	< 0.005
7	Rb	Rb = 0.427Vb	0.75	< 0.005
8	Rh	Rh = 0.271Vb	0.35	< 0.050
9	C1toe	C1toe = 0.083Vb	0.50	< 0.050
10	Cmb	Cmb = 0.136Vb	0.45	< 0.050
11	Cins	Cins = 0.221Vb	0.51	< 0.050
12	Cla	Cla = 0.247Vb	0.78	< 0.005
13	Vmb	Vmb = 0.957Vb	0.88	< 0.005
14	Vlb	Vlb = 0.975Vb	0.89	< 0.005

N°	Foot parameters	Regression	r	p
15	Vw	Vw = 0.976Vb	0.86	< 0.005
16	Vins	Vins = 1.017Vb	0.84	< 0.005
17	Vh	Vh = 1.306Vb	0.72	< 0.005
18	Va	Va = 0.850Vb	0.64	< 0.005

Currently, the most commonly used shoe size systems are the French (European), British, American, and Mondopoint sizing systems. The basis for determining shoe sizes of the French, British and American size systems is the insole length. The length increments for these size systems are 6.66 mm (French system), 8.46 mm (British and American systems), and are 3.33 and 4.23 mm, respectively. The Mondopoint sizing system determines the size according to the foot length. The increments in foot length are 10 mm, for half size is 5 mm.

Research results on female diabetic feet in Vietnam [15, 16] show that the French size system, with length increments of 6.66 mm, can be rounded by 6.5 mm, which is a reasonable choice. This increment is about two-thirds of the standard deviation of the foot length, making it easy to choose shoes, as well as ensuring the right number of sizes. Therefore, in this study, the foot size system was also built on the basis of the French size system.

Building the Size Structure by Foot Length

The theoretical value of the part a_j of size j is equal to the probability (frequency) of the normal distribution of the value Bз in the corresponding j interval ($X_j^н$, $X_j^в$), where $X_j^н$, $X_j^в$ are the lower and upper limits of the j interval [27]. $a_j = P(X_j^н < Bз < X_j^в) » Φ(Z_j^в) – Φ(Z_j^н)$, where Φ(Z) – Laplace function, defined according to the table of values by the values of $Z_j^в$ and $Z_j^н$: $Z_j^в = (X_j^в – X)/d$ and $Z_j^н = (X_j^н – X)/d$ (where d is the standard deviation). The set of a_j values for all foot length classes is the foot size structure by length [19] (see Table 5).

Table 5: Results of calculating the foot size structure by length

Foot sizes by length, mm	Limit values of the class X, mm		Standard value Z		Values of the Laplace function Φ(Z)		$P(Bз_j^н < Bз < Bз_j^в)$	Relative percentage $α_j$
	$Bз_j^н$	$Bз_j^в$	$Z_j^н$	$Z_j^в$	$Φ(Z_j^н)$	$Φ(Z_j^в)$		
218.5	216	221	-3.2386	-2.670	0.0010	0.0038	0.003	0.003
225.0	222	228	-2.5568	-1.880	0.0052	0.0301	0.025	0.030
231.5	*229*	*234*	*-1.7614*	*-1.190*	*0.0392*	*0.1170*	*0.078*	*0.093*
238.0	*235*	*241*	*-1.0795*	*-0.400*	*0.1400*	*0.3446*	*0.202*	*0.241*
244.5	*242*	*247*	*-0.2841*	*0.284*	*0.3897*	*0.6103*	*0.221*	*0.263*
251.0	*248*	*254*	*0.3977*	*1.080*	*0.6600*	*0.8599*	*0.205*	*0.244*
257.5	*255*	*260*	*1.1932*	*1.761*	*0.8830*	*0.9608*	*0.078*	*0.093*
264.0	261	266	1.8750	2.443	0.9700	0.9924	0.023	0.028
270.5	267	273	2.5568	3.239	0.9948	0.9999	0.005	0.006
			Total					1,0

When developing a sizing system, sizes with a frequency greater than 3% or more are considered. Therefore, it is recommended to build a sizing system by foot length with 5 sizes from 231.5 mm to 257.5 mm. It responded to 93.3% of diabetic men's feet by foot length.

Building the Size Structure by Width

According to the foot length in the range of sizes 231.5 ÷ 257.5 mm, the average ball girth of each foot size is determined. The number of sizes by width/ball girth to be set up is shown in Table 6. According to the data in Table 6, the ball girth difference between the smallest size and the largest size is 18.7 mm. With an increase in foot length by 6.5 mm, the average ball girth increase is 4.7 mm. Approximately 5 width sizes are required for each foot length, when using 10 mm ball girth increments.

Table 6: Results of determining average ball girth values (Vb) of foot sizes and number of foot sizes by width

Foot sizes by length, mm	Min of Vb, mm	Max of Vb, mm	Average of Vb, mm	Difference of Vb by length, mm	Selected Vb value, mm	Difference between Max and Min of Vb, mm	Number of sizes by width to be set in 10 mm increments
231.5	212	250	231.4		231	38	3.8
238.0	211	260	235.4	4.0	236	49	4.9
244.5	220	271	240.3	4.9	241	51	5.1
251.0	220	270	245.5	5.2	246	50	5.0
257.5	224	271	250.1	4.6	251	47	4.7

Table 7: Result to calculate foot size by width

Foot sizes by length, mm	Response rate, %, with	
	5 sizes by width	3 sizes by width
231.5	100.0	90.5
238.0	100.0	87.5
244.5	98.1	85.7
251.0	99.5	86.0
257.5	100.0	87.2
Average	99.5	87.4

The results of calculating the number of foot sizes by width with ball girth increments of 10 mm are shown in Table 7.

The use of 5 sizes in width meets up to 99.5% of survey subjects but is not feasible. In the United States, diabetics receive therapeutic shoes manufactured in three sizes by width [20]. Therefore, in this study, three sizes by width in increments of 10 mm were used. It responds to 87.4% of diabetic men's feet. This allows to reduce the number of sizes, and the built-in sizing system will be adapted to the actual shoe production.

Thus, for diabetic men's feet in Vietnam, a foot size system with 5 sizes by length (from 231.5 mm to 257.5 mm) and 3 sizes by width for each size by length should be used. The size system includes 15 sizes that can accommodate over 81.5% of the patient's feet in length and width (Table 8).

Table 8: Diabetic men's foot sizes by length and width

Foot sizes by length, mm	Foot sizes by width, mm		
231.5	221	231	241
238.0	226	236	246
244.5	231	241	251
251.0	236	246	256
257.5	241	251	261

Determining the Foot Parameters for the Size System

To obtain a foot size system in 5 sizes by length (231.5, 238, 244.5, 251, 257.5 mm) and 3 sizes by width, it is necessary to determine the remaining parameters according to the dominant parameters, using the built-in regression equations, that are shown in Table 4. Examples of foot size in length 244.5 mm with 3 sizes by width (A – small, B – medium, C – large) are shown in Table 9.

Table 9: The foot parameters of diabetic men in Vietnam of size 244.5 mm by length with 3 sizes by width

№	Foot parameters	Values by width, mm		
		A	B	C
1	Lf	244.5	244.5	244.5
2	Lmb	180.0	180.0	180.0
3	Llb	159.4	159.4	159.4
4	L5toe	202.4	202.4	202.4
5	Lgot	78.5	78.5	78.5
6	Lla	55.7	55.7	55.7
7	Rmb	95.4	99.5	103.7
8	Rlb	92.2	96.2	100.1
9	Rb	98.6	102.9	107.2
10	Rh	62.6	65.3	68.0
11	C1toe	19.2	20.0	20.8
12	Cmb	31.4	32.8	34.1
13	Cins	51.1	53.3	55.5
14	Cla	57.1	59.5	62.0
15	Vmb	221.1	230.6	240.2
16	Vlb	225.2	235.0	244.7
17	Vb	231.0	241.0	251.0
18	Vw	225.5	235.2	245.0
19	Vins	235.0	245.1	255.2
20	Vh	301.7	314.7	327.8
21	Va	196.4	204.9	213.4

CONCLUSIONS

In this study, the anthropometric characteristics of Vietnamese men's feet with diabetes were investigated. Various types of diabetic foot lesions have been evaluated. Common types of foot injuries are painful feet, swollen ball joints, foot ulcers, dry, cracked skin, and calluses of the feet. The patient's foot deformity is mild. The position of deformity is concentrated in the forefoot. These are the common lesions found in diabetic feet and are consistent with published studies on diabetic foot complications [1-12].

There were significant differences in the parameters according to the width and circumference of the feet of diabetic men and those of healthy men's feet. This suggests the need to develop their own foot sizing system. The foot sizing system has been developed that includes 5 sizes by length (231.5, 238, 244.5, 251, 257.5 mm). Each size by length has 3 sizes by width. This is an important basis for designing shoe-lasts, designing and providing footwear for men with diabetes in Vietnam.

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POLYMER COMPOSITE BASED ON NBR RUBBER COMPOUNDED WITH RUBBER WASTE FUNCTIONALIZED WITH POTASSIUM OLEATE

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POLYMER COMPOSITE BASED ON NBR RUBBER COMPOUNDED WITH RUBBER WASTE FUNCTIONALIZED WITH POTASSIUM OLEATE

ABSTRACT. Waste is a material that occurs as a result of a biological or technological process that can no longer be used as such. Recycling and reusing waste make it possible to contribute to environmental protection and, of course, to the protection of human health by eliminating toxins during waste incineration. The purpose of this paper is to process and characterize polymer composites based on NBR rubber (butadiene-co-acrylonitrile rubber) and rubber waste functionalized with potassium oleate in terms of rheological characteristics (to determine the optimal vulcanization time), Brabender diagrams and physico-mechanical properties in normal state and after accelerated ageing at 70°C, for 168 h (using elastomer-specific equipment). Functionalized rubber waste (with potassium oleate up to 20% at 60°C) is introduced into the mixture in proportions of 10; 20; 30; 50%. The polymeric composites based on butadiene-co-acrylonitrile elastomer and rubber waste (ground with a cryogenic mill at 10,000 rpm, at the size of 0.35 mm) were compounded on a mixer with a capacity of 350 cm3 according to the working recipes. The mixtures were supplemented with vulcanization activators and accelerators on an electric roller, resulting in formulations in the form of 4 mm thick sheets, which are then subjected to the relevant characterizations according to the standards in force for the footwear industry.

KEY WORDS: NBR rubber, rubber waste, compounding, vulcanization, polymer composite

COMPOZIT POLIMERIC PE BAZĂ DE CAUCIUC NBR COMPOUNDAT CU DEȘEU DE CAUCIUC FUNCȚIONALIZAT CU OLEAT DE POTASIU

REZUMAT. Deșeul este un material ce apare în urma unui proces biologic sau tehnologic ce nu mai poate fi utilizat ca atare. Prin reciclarea și reutilizarea acestora se poate contribui la protecția mediului și, bineînțeles, la protejarea sănătății umane prin eliminarea toxinelor din timpul incinerării acestora. Scopul acestei lucrări este procesarea și caracterizarea din punct de vedere reologic (pentru determinarea timpului de vulcanizare optim), al diagramelor Brabender și fizico-mecanic în stare normală și la îmbătrânire accelerată la 70°C, timp de 168 h (pe aparatură specifică elastomerilor), a compozitelor polimerice pe bază de cauciuc NBR (cauciuc butadien-co-acrilonitril) și deșeu de cauciuc funcționalizat cu oleat de potasiu. Deșeul de cauciuc funcționalizat (cu oleat de potasiu până la 20% la temperatura de 60°C) este introdus în amestec în proporții de 10; 20; 30; 50%. Compoundarea compozitelor polimerice pe bază de elastomer butadien-co-acrilonitril și deșeu de cauciuc (măcinat cu o moară criogenică la 10.000 rot/min, la dimensiunea de 0,35 mm) s-a realizat pe un malaxor de capacitate de 350 cm3 conform rețetelor de lucru. Amestecurile au fost completate cu acceleratori și activatori de vulcanizare pe un valț electric, obținându-se recepturi sub formă de foi de 4 mm grosime. Apoi acestea sunt supuse caracterizărilor aferente conform standardelor în vigoare pentru industria de încălțăminte.

CUVINTE CHEIE: cauciuc NBR, deșeu cauciuc, compoundare, vulcanizat, compozit polimeric

COMPOSITE POLYMÈRE À BASE DE CAOUTCHOUC NBR MÉLANGÉ AVEC DES DÉCHETS DE CAOUTCHOUC FONCTIONNALISÉ AVEC DE L'OLÉATE DE POTASSIUM

RÉSUMÉ. Un déchet est un matériau résultant d'un processus biologique ou technologique qui ne peut plus être utilisé en tant que tel. En le recyclant et en le réutilisant, il est possible de contribuer à la protection de l'environnement et bien sûr à la protection de la santé humaine en éliminant les toxines lors de l'incinération des déchets. Le but de cet article est de traiter et de caractériser un composite polymère à base de caoutchouc NBR (caoutchouc butadiène-co-acrylonitrile) et de déchets de caoutchouc fonctionnalisés avec de l'oléate de potassium en termes de caractéristiques rhéologiques (pour déterminer le temps de vulcanisation optimal), de diagrammes de Brabender et de propriétés physico-mécaniques à l'état normal et après vieillissement accéléré à 70°C, pendant 168 h (sur équipement spécifique pour l'élastomère). Des déchets de caoutchouc fonctionnalisés (avec de l'oléate de potassium jusqu'à 20% à 60°C) sont introduits dans le mélange dans des proportions de 10 ; 20 ; 30 ; 50 %. Le compoundage des composites polymériques à base d'élastomère butadiène-co-acrylonitrile et de déchets de caoutchouc (broyé au broyeur cryogénique à 10 000 rpm, à la taille de 0,35 mm) a été réalisé sur un malaxeur d'une capacité de 350 cm3 selon les recettes de travail. Les mélanges ont été complétés avec les activateurs et accélérateurs de vulcanisation sur rouleau électrique, obtenant des feuilles de 4 mm d'épaisseur, qui sont ensuite soumis aux caractérisations pertinentes selon les normes en vigueur pour l'industrie de la chaussure.

MOTS-CLÉS : caoutchouc NBR, déchets de caoutchouc, compoundage, vulcanisé, composite polymère

INTRODUCTION

In December 2015, the European Commission adopted a "circular economy" package to help businesses and European consumers make the transition to a sustainable resource economy. The Romanian government has also issued a series of government decisions related to waste management. Government Decision no. 856/2002 - "Introduction of waste management records and the European Waste Catalogue" is the most important in this context [1-3]. Recycling and reusing waste make it possible to contribute to the environmental protection and, of course, to the protection of human health by eliminating toxins during waste incineration, and implicitly to a turnover increase for economic agents [4, 5]. Reusing and recycling polymeric waste are real options to reduce the amount of waste and thus their impact on the environment, as required by Directive 2008/98/EC [6]. A possible alternative is the transformation of long-lasting polymer waste into biodegradable polymer composites, thus considerably reducing their life span. The reprocessing of polymer waste involves decontamination, grinding, densification, as well as the storage of flakes, fibers or waste granules and their reuse [7].

The disposal of polymeric waste generates serious economic and environmental concerns, and waste management is becoming an important social issue. Given the environmental awareness in society, the most viable option for the treatment of polymer waste remains recycling [1, 6]. Thermal decomposition of polymer waste in an incinerator causes environmental problems, through the release of carbonic acids, sulfur oxides, carbon oxides, etc.

Recently, polymer composites based on elastomers have been intensively studied especially for the domestic, gardening, automotive and aeronautical fields, but also for the footwear industry [7-9]. In the structure of composite materials there are also elastomers that allow vulcanization to occur. Once the vulcanization process takes place, the elastomers keep their shape, but this process also influences their characteristics. NBR elastomer (butadiene-co-acrylonitrile rubber is an elastic elastomer) is used due to properties such as high abrasion resistance and high temperature stability, from -40 to +108°C (-40 to +226°F), making it an ideal material for aeronautical applications [10-14]. It also has a very good resistance to mineral oils, petroleum products, aging resistance and low gas permeability, being used to produce castings, footwear, adhesives, sponges, expanded foam, etc. and conveyor belts for tires (for trucks and cars) in the automotive industry. By adding other substances such as vulcanization activators and accelerators – sulfur, tetramethyl thiuram, etc. – the physical and mechanical properties of the resulting products are improved [15, 16].

Polymer composites based on NBR elastomer (butadiene-co-acrylonitrile) and rubber waste (ground to a size of 0.35 mm with a cryogenic mill at a speed of 10,000 rpm) were obtained on a Brabender Plasti-Corder mixer with a capacity of 350 cm^3, according to working recipes. The mixtures were completed with the same vulcanizing agents and activators (sulfur and tetramethyl thiuram – Th) on an electric roller at a temperature of 25-30°C, friction of the rollers 1:2, with 50 rpm, obtaining recipes in the form of 4 mm thick sheets. Then the rheological test was performed on a Monsanto Rheometer to determine the optimal vulcanization times for the electric press, in molds specific to elastomeric composites. Plates are obtained from which specimens for physical-mechanical characterization are stamped according to the standards in force. After conditioning for 24 hours at room temperature, the specimens are subjected to physical-mechanical determinations: normal state at room temperature and after accelerated aging at 70°C for 168 hours [17-19].

EXPERIMENTAL

Materials

Materials used were: (1) butadiene-co-acrylonitrile rubber (NBR rubber): acrylonitrile content – 34%; Mooney viscosity (100%) – 32±3; density – 0.98 g/cm^3; (2) Stearin: white flakes; moisture - 0.5% max; ash – 0.025% max; (3) zinc oxide microparticles (ZnO): white powder, precipitate 93-95%, density – 5.5 g/cm, specific surface – 45-55 m^2/g; (4) silicon dioxide (SiO_2): density – 1.9-4.29 g/cm^3, molar mass – 60.1

g/mol; (5) Kaolin: white powder, molecular weight 100.09; (6) protein waste: ground leather functionalized with potassium oleate; (7) rubber waste - ground rubber from the footwear industry; (8) mineral oil; (9) N-isopropyl-N'-phenyl-p-phenylenediamine (IPPD 4010): density – 1.1 g/cm^3, solidification point over 76.5°C, flat granules coloured brown to dark purple); (10) Sulphur (S): vulcanization agent, fine yellow powder, insoluble in water, melting point: 115°C, faint odor; (11) tetramethylthiuram disulfide (Th): curing agent, density – 1.40g/cm^3, melting point <146°C, an ultrafast curing accelerator.

Methods

Preparation of Polymer Composite Based on NBR Rubber and Functionalized Rubber Waste

Vulcanized polymer composites with functionalized rubber waste were made by compounding technology on a Brabender Plasti-Corder mixer with the possibility of adjusting the temperature and mixing speed, with a capacity of 350 cm^3, in strict compliance with the order of introduction of ingredients, Table 1. The mixtures made in Brabender Plasti-Corder were completed with vulcanizing agents on a laboratory roller. The processed recipes are rheologically tested with the help of a Monsanto 100S Rheometer to determine the optimal vulcanization times in the electric press at controlled pressure and temperature. In the first phase, plates are processed from which specimens for physical-mechanical and physical-chemical characterization are stamped at the optimal technological processing parameters established after the rheological testing. After conditioning for 24 hours at room temperature, the plates are subjected to physical-mechanical determinations in normal state (at room temperature) and after accelerated aging at 70°C for 168 hours.

Table 1: Formulation of polymer composite based on butadiene-co-acrylonitrile rubber (NBR) compounded with butadiene-co-acrylonitrile (NBR) rubber waste functionalized with potassium oleate

Symbol	MU [g]	BO (control)	B0$_1$	BCO$_1$	BCO$_2$	BCO$_3$	BCO$_4$
Butadiene-co-acrylonitrile (NBR)	g	150	150	150	150	150	150
Stearin (flakes)	g	1.8	1.8	1.8	1.8	1.8	1.8
Zinc oxide (ZnO – active powder)	g	7.5	7.5	7.5	7.5	7.5	7.5
Silicon dioxide (SiO_2)	g	45	-	30	20	-	-
Kaolin	g	37	37	37	37	37	37
Functionalized rubber waste (NBR) with potassium oleate	g	-	-	15	30	45	75
Non-functionalized rubber waste – NBR, (10%)	g	-	15	-	-	-	-
Mineral oil	g	14.9	14.9	14.9	14.9	14.9	14.9
IPPD 4010	g	4.5	4.5	4.5	4.5	4.5	4.5
Roller mixing							
Sulfur (S)	g	2.3	2.3	2.3	2.3	2.3	2.3
Tetramethylthiuram disulfide (Th)	g	1	1	1	1	1	1

BO – composite without waste;
B0$_1$ – composite with 10% non-functionalized waste

For the good processing of polymeric composites based on butadiene-co-acrylonitrile rubber and functionalized rubber waste in a proportion of 10, 20, 30, 50%, the initial working temperature was set at 40°C. For each mixture, the variation of torque and temperature over time was recorded, Table 2.

Table 2: Working method using the Brabender Plasti-Corder mixer

Order of introducing ingredients	Time (minutes)	Rate	Temperature, °C
Butadiene-co-acrylonitrile rubber (plasticizing)	1'30"	40 rpm	40°C
Ingredients (without vulcanization agent)	4'30"	20 rpm	40°C
Homogenisation	3'	80-100 rpm	80-100°C

Before being introduced into the polymer mixture the NBR rubber waste was ground to a size of 0.35 mm using a cryogenic mill at a rate of 10,000 rpm. After the grinding process, the resulting waste was functionalized with potassium oleate in a proportion of 20%, at a temperature of 60°C.

After the mixture is processed using the Brabender mixer, it is then processed on an electric roller, adding vulcanizing agents, sulfur and TH, at temperatures of 25-30°C, friction of the rollers 1:2, at 50 rpm. The working method is as follows:

- the raw materials, sulfur (S) and tetramethylthiuram (Th) are dosed;
- the composite is plasticized using the Brabender Plasti-Corder mixer;
- vulcanizing agents (S and Th) are introduced and mixed for 5-7 minutes;
- the mixture is homogenized on a roller for 1-2 minutes and removed in the form of a sheet about 4 mm thick. The mixture is then left at ambient temperature for 24 hours for characterization.

RESULTS AND DISCUSSIONS

Characterization of Brabender Processing Diagrams

According to the recorded Brabender diagrams, Figure 1, it can be observed that the samples obtained by the mixing technique on the Brabender Plasti-Corder were made using the working method presented in Table 2. In the first portion, A-B, which lasts 1’30’’ at 40 rpm, the NBR elastomer (butadiene-co-acrylonitrile rubber) is introduced into the mixer, so that the torque increases. Therefore, the first loading peak, A, corresponds to the introduction of the NBR elastomer. As the torque increases, so does the temperature due to the friction of the screws of the Brabender Plasti-Corder mixer. Due to the homogenization and plasticization of the NBR elastomer, as well as due to the increase in temperature due to shearing, we can see that the torque begins to decrease near A towards B. Then the other ingredients are introduced and the rotation speed is reduced to 20 rpm for 4’30’’. The mixer is kept open until all the ingredients are incorporated according to the recipe, Table 1.

As a result of the incorporation of the ingredients, but also of the compaction and reinforcement of the elastomer, the torque between point B and point X begins to increase. After incorporating the fillers and other ingredients into the mixture, the second loading peak, X, is observed, thus appearing a maximum torque. When the torque begins to decrease, it indicates that homogenization of the compound is taking place for 3’ at 80-100 rpm, during which time the mixer remains closed. As a result, a maximum torque value is obtained due to the compaction and homogenization of the elastomer mixture. Then there is a decrease in torque, which indicates the homogenization of the mixture, as well as an increase in its temperature due to friction at a higher rotational speed, with the Brabender mixer kept closed.

Table 3: Characteristics presented in Brabender processing diagrams for composites based on butadiene-co-acrylonitrile rubber (NBR) compounded with rubber waste

Characteristics	BO (control)	$B0_1$	BCO_1	BCO_2	BCO_3	BCO_4
Temperature at loading peak, °C	70	88	50	68	64	85
Temperature at inflection point, °C	94	95	96	93	86	69
Maximum temperature, °C	106	107	107	104	92	79
Energy at loading peak, kNm	138.8	118.6	159.8	14.04	5.0	130.6
Maximum energy, kNm	138.7	107.2	124.0	119.1	215.6	1.9
Gelation area energy, kNm	30.2	39.2	38.4	31.4	2.7	25.9
Specific energy, kNm/g	1.3	1.0	1.2	1.1	0.9	0.6
Gelation rate, Nm/min	-28.0	-20.5	-18.8	-21.7	-85.4	188.4

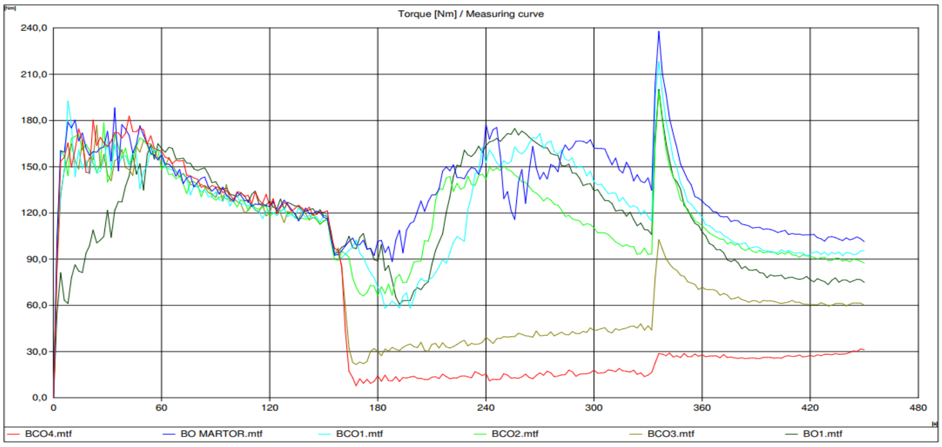

Figure 1. Torque variation over time, recorded with Brabender Plasti-Corder when obtaining polymer composites based on NBR rubber compounded with rubber waste functionalized with potassium oleate

Rheological Characterization of Polymer Composite Based on NBR Rubber

The rheological characteristics of the polymer composites based on NBR rubber compounded with NBR rubber waste functionalized with potassium oleate are obtained using a Monsanto Rheometer, at 165°C, for 24', Table 4, establishing the optimal vulcanization times in the electrical press to obtain specimens that will then be subjected to physical-mechanical, chemical and morpho-structural testing.

The analysis is performed as follows: a sample of maximum 8-10 g is sealed in a cavity of the device, at a controlled and constant temperature, which surrounds a rotor with oscillations at a frequency of 1.67 Hz (100 cpm). The output correlates with the degree of vulcanization depending on the vulcanization time.

Table 4: Rheological characteristics of polymeric composite based on NBR rubber compounded with rubber waste

Rheological characteristics at 165°C	BO (control)	BO_1	BCO_1	BCO_2	BCO_3	BCO_4
ML (dNm)	1.3	15.7	17.1	17	11.9	12.9
MH (dNm)	46.9	37.4	47.8	44.5	36.1	38.2
ΔM = MH-ML (dNm)	29.6	21.7	30.7	27.5	24.2	25.3
t_{s2} (min)	2.91	2.64	2.78	2.48	2.03	1.68
t_{50} (min)	6.38	3.6	3.87	3.39	2.86	2.51
t_{90} (min)	18.61	8.68	5.45	4.94	8.78	11.21

From the presented data, Figure 2, it is observed that by replacing the quantity of precipitated chalk as inactive filler with elastomeric waste, the rheological characteristics of the mixtures are modified as follows:

- the minimum torque (ML) shows a variation of +5-(-20)%, the maximum torque (MH) shows a decrease of max. 28%, and the variation of the torque (ΔM) decreases by max. 41% as the amount of NBR rubber waste increases, to the detriment of the amount of mineral filler, indicating the decrease of the rigidity of the rubber mixtures in vulcanized state;
- for all samples the reversal phenomenon is observed, which is specific to the mixtures vulcanized with sulfur and vulcanization accelerators, indicating a degradation of the mixtures at high temperatures by breaking some crosslinking bonds;

- the scorching time (t_{s2}) decreases as the amount of rubber waste increases and the amount of mineral filler decreases, and the optimal vulcanization time increases by replacing it with elastomeric waste.

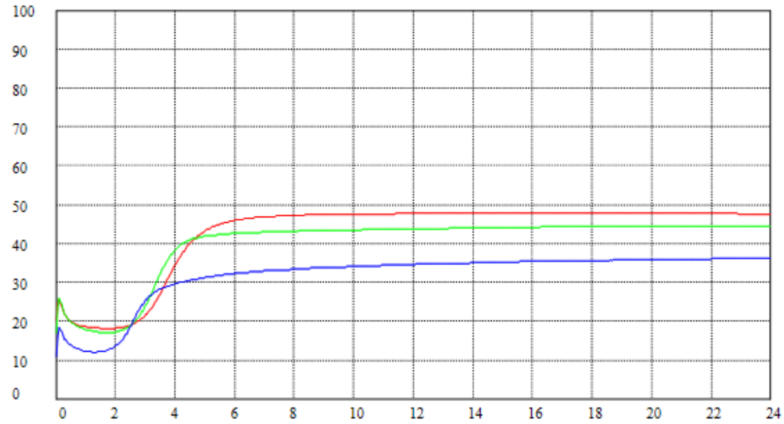

Figure 2. Torque variation expressed in dNm (OY axis) over time expressed in minutes (OX axis) for samples with rubber waste functionalized with potassium oleate: BCO_1 (red) – 10% waste, BCO_2 (green) – 20% waste, BCO_3 (blue) – 30% waste

Physical-Mechanical Characterisation of Polymer Composites Based on NBR Rubber

Physical-mechanical characterization of samples in normal state and after accelerated aging at 70°C and 168 hours was performed according to the standards in force by the following methods: hardness, elasticity, tensile strength. Table 5 shows the values of the physical-mechanical tests performed according to the standards in force.

Table 5: Physical-mechanical characterisation of polymer composites based on NBR rubber compounded with rubber waste

Sample	BO (control)	BO_1	BCO_1	BCO_2	BCO_3	BCO_4
Physical-mechanical characteristics: Normal State						
Hardness, °Sh A	61	47	57	55	50	47
Elasticity, %	18	20	18	18	16	16
Modulus 100%, N/mm^2	1.16	0.82	1.18	1.19	0.96	0.93
Tensile strength, N/mm^2	11.3	3.29	9.15	6.77	3.8	2.6
Elongation at break, %	180	480	760	700	560	380
Residual elongation, %	80	16	28	28	24	20
Tear strength, N/mm	42.9	16.05	33.25	30.6	17.8	14.56
Specific weight, g/cm^3	124	1.08	1.19	1.19	1.15	1.07
Resistance to abrasion, mm^3	218.39	80.62	181.12	138.17	112.08	79.87
Physical-mechanical characterization: Accelerated ageing at 70°C and 168 h						
Hardness, °Sh A	66	51	61	57	54	48
Elasticity, %	24	24	22	22	20	16
Modulus 100, N/mm^2	1.6	0.97	1.44	1.41	1.22	0.92
Tensile strength, N/mm^2	14.47	2.86	10.14	6.86	32	2.02
Elongation at break, %	980	400	740	580	400	320
Residual elongation, %	60	16	32	20	20	12
Tear strength, N/mm	53.7	16.4	44.1	34.950	18.5	1.22

From the presented data it is observed that by replacing the amount of silicon dioxide with NBR rubber waste, the physical-mechanical characteristics of the mixtures are modified as follows:

- hardness decreases by max. 6°ShA in samples containing less silicon dioxide and more rubber powder;
- the elasticity decreases proportionally with the increase of the waste percentage;
- the values of tensile and tear strength gradually decrease as the active filler of silicon dioxide is replaced by elastomeric waste, but has good values, of 3.8 N/mm^2, respectively 17.8 N/mm for sample BCO_3;
- elongation at break has good values, over 700%, in the BCO_3 sample (composite with 30% elastomeric waste);
- the abrasion resistance decreases proportionally with the increase of the waste quantity and presents a value that falls within the standard (minimum 200 mm^3);
- the density of the mixtures decreases as the amount of powder increases, indicating, in conjunction with the other properties, a better compatibility between NBR rubber and the waste of the same type of elastomer;
- after accelerated aging for 168 h at 70°C of the samples, the following are observed: increases in hardness of +2-6°ShA and smaller variations of the tensile and tear strength (of max. 21%, respectively of max. 10%).

CONCLUSION

This paper presents the technology for making polymer composites based on NBR rubber compounded with rubber waste, but also the characterization of Brabender Plasti-Corder mixer diagrams, from a rheological and physical-mechanical point of view according to the standards in force using equipment specific for elastomers. The rubber waste was ground with a cryogenic mill at a size of 0.35 mm at a rate of 10,000 rpm and then functionalized with potassium oleate. Functionalization was performed at temperatures of 60°C.

Following the rheological characterizations of the polymeric composites based on NBR rubber compounded with NBR rubber waste functionalized with potassium oleate, the optimal vulcanization times in the electrical press were established for obtaining specimens. According to the recorded Brabender diagrams, the samples are obtained by the mixing technique, complying with the established working mode. Following the physical-mechanical characterization of samples in normal state and after accelerated aging at 70°C, for 168 h, it is observed that the mixtures were carried out according to the working recipes at the optimal parameters and working times.

Polymer composites based on butadiene-co-acrylonitrile (NBR) elastomer and rubber waste functionalized with potassium oleate have optimal values according to the standards and have potential applications in the domestic field, in consumer goods for general use, but also in automotive and aeronautics.

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EUROPEAN RESEARCH AREA

COTANCE NEWSLETTERS

Starting with January 2019, the COTANCE Council will issue a monthly ***COTANCE Newsletter*** with the purpose of **promoting an improved image of leather** to relevant decision makers and domestic stakeholders including Members of the European and National Parliament, Governmental authorities, Ministerial officers, Customers of the leather industry, Brands, Retail chains, Relevant NGOs, Designers, etc. The monthly newsletters present topics that tell the truth about a controversial aspect or a fact that is not well known by the general public to bring about a better understanding of leather and the European leather industry, as well as a positive predisposition to legislate in favor of the leather industry. The newsletters are available in seven languages at https://www.euroleather.com/index.php/newsletter, and were also published in the 2019-2021 issues of *Leather and Footwear Journal*. Newsletters 1-3 of 2022 are given below.

NEWS 1/2022

Go for Slow Fashion – *choose leather!*

There was a time, not so long ago, when we were living in a throw-away society. New cheap materials were even introduced, promoting this mentality. Today, however, we are aware of the importance of sustainability and the necessity to take responsibility for our purchasing choices. We can no longer afford to live in a world with a throw-away state of mind.

With resources shrinking and waste accumulating, **it is our responsibility** not only to choose well, but also to stretch the lifetime of, the products we buy. **We need to slow down** if we want to save the planet.

Products that last longer help us to have a much lower environmental footprint as the environmental impact of their production is stretched over the duration of their use. It goes without saying that longer living products need materials that are reliable and age well.

The world needs materials that are sustainable; materials that come from a renewable source, **are fit for use, recyclable, biodegradable and don't add to the burden of atmospheric carbon**.

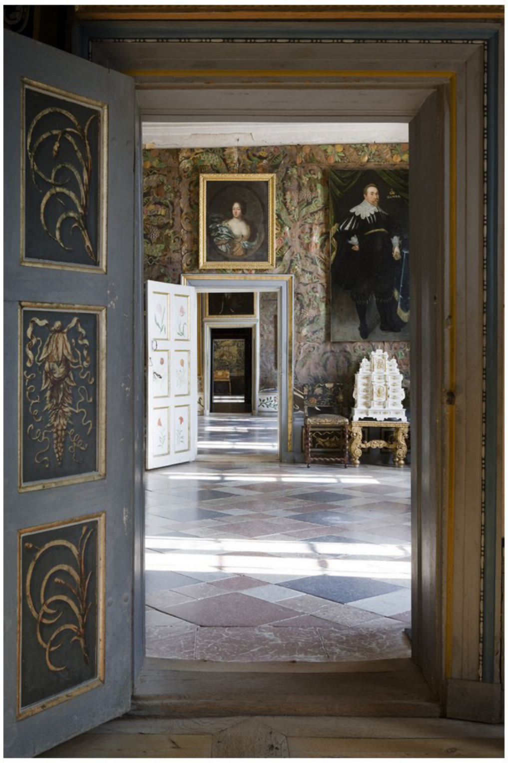
And guess what? Leather meets these requirements.

Frank Recht leather chair

COTANCE Member associations represent 1479 tanneries producing to strict environmental standards, the leather that will extend the usable lifetime of products, providing a feeling of beauty and a sense of high quality.

Indeed, good quality leather upholstered furniture can last 10 to 25 years with appropriate care and some may even last a lifetime. This black-and-red chair shows two sides: the red side has hardly been maintained for 15 years while the black side has received **appropriate care** and been recoloured. After 20 years, it looks as good as new.

Built between 1654 and 1676, the baroque *Skokloster Castle* in Sweden gives us another example. Its shiny gilt leather hangings commissioned for the state apartments can still be admired after more than 350 years. Talk about longevity and sustainability!



The Wrangel apartment
with close-up of gilt leather hangings.
Gilt leather making was a craft
that originated in North Africa.
It spread in the Late Middle Ages
through Spain to the rest of Europe.

Pictures: Skokloster Castle

The leather manufacturing sector upcycles an unavoidable residue from the food industry, to produce a beautiful versatile, durable, unique material, ideal for the circular economy. **Go slow, choose leather!**

edited bv — in collaboration with

COTANCE — SWEDISH TANNERS EST. 1902 — VDL Verband der Deutschen Lederindustrie e.V.

NEWS 2/2022

Leather and deforestation; not to blame but willing to help

Due to its link with the meat industry, leather is often claimed to be a cause of the deforestation in vulnerable environments, such as the Amazon. Reports by NGOs have attempted to associate fashion brands and automotive companies to deforestation and leather is one of the commodities that may be subject to new due diligence requirements contained in proposed regulations in the EU, UK and possibly, the USA.

These concerns have given rise to considerable activity by the industry to **improve transparency and traceability within the leather supply chain**. Action has been taken to ensure, as far as possible, that the leather supply chain does not contain hides sourced from illegally deforested areas and to give confidence to downstream customers and consumers that their products are not contributing to deforestation.

The leather industry deplores the destruction of the planet's rain forests

However, it must be understood that **leather does not drive the rearing of livestock**. The production of leather is all but incidental to that. By extension, **it does not drive deforestation**. Research at the University of Montana has shown that demand for hides for leather has no direct influence on the number of animals reared and slaughtered. This means that even the best efforts of the leather sector will have a limited impact in the fight against illegal deforestation.

Video screenshot showing unused hides being thrown away.
Taken from LinkedIn (October 28, 2019)

It must also be recognised that the illegal deforestation in the regions of concern is due to corruption, abuses of power, 'land grabbing' and 'cattle laundering'. Even the most diligent companies could be misled on the provenance of the raw materials that they source, particularly from its indirect suppliers. Moreover, most tanneries are small, which exacerbates the challenge. **As a customer of the meat industry, leather manufacturers are excluded from the first stages of the supply chain and are not involved in the sourcing and tracing of livestock**. Furthermore, hides or skins are of little importance to the meat value chain; hides may represent as little as 0.8% of the animal's value, and globally, up to 40% are simply thrown away.

The leather sector has very little scope to influence the upstream supply chain. Farmers are paid for the whole animal and receive no premium for the hide or skin. As such, hides and skins have no influence on the rearing of livestock. Hence, **while** the leather industry supports the elimination of deforestation-sourced raw materials from its supply chain, the limitations on its influence on that part of the supply chain **must be recognised and expectations must be tempered with pragmatism**. Stigmatising leather by defining it legally as a deforestation risk product is unfair and unhelpful.

Nonetheless, the global leather industry does not deny its place in supply chains that carry deforestation risks, and it will play its part in seeking to resolve the issues by pushing for increased transparency and traceability of raw materials. **By engaging with our suppliers and insisting on change, leather manufacturers and their customers can be part of the solution.**

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ASSOCIAÇÃO PORTUGUESA DOS INDUSTRIAIS DE CURTUMES

leather from portugal

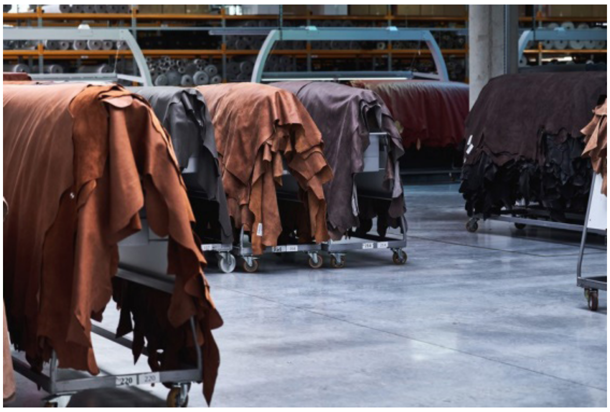
NEWS 3/2022

Innovation: drivers for the future

Innovation has always been necessary, but with emerging trends such as an increasing global population, urbanization, pressure on food production and climate change, the challenges for innovation in sustainability have increased.

The European tanning sector began its journey of innovation many years ago, with investment in industrial automation and technological evolution of production processes. More recently, progress has been seen in the use of digital technology and product research to stimulate green transformation. European tanners aim for long-term sustainable growth while enhancing their ability to respond to rapid market changes.

There are plenty of concrete successes along the innovation path of Europe's tanning sector.



Take for example the use of enzymes in the soaking and liming processes where hides or skins are cleaned. These enzymes open the pores of the hides and skins, gently releasing the hair which can be recovered as a by-product. As it is free of harsh chemicals, this recovered hair or wool can then be reused as a resource, illustrating the circularity of the tanning industry.

But environmental considerations are not the only drivers of innovation in the tanning industry. Increases in energy or raw material costs can also be a driver, notably in process efficiency. High exhaustion tanning processes, heat pumps and automated drum feeding contribute to the saving of valuable resources, which is further enhanced by digitalization.

The future will bring automated plants equipped with sensors to monitor production processes. This will lead to greater production flexibility, while minimizing the use of water, energy and chemicals, and at the same time, limit the risks in the workplace related to the human/machine interface or exposure to chemical products.

The passion for continuous innovation is transmitted to the younger generation of tanners in the courses taken in Europe's reputed vocational education & training institutions.

Finally, the need for research and innovation in the tanning industry derives also from the cultural and creative side of the leather business. Success on the European leather market requires constant customization of technological solutions. European tanners continue to develop an extremely varied and ever-changing product portfolio. This is what makes European leather special and different to all others.

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NEWS RELEASE FROM THE IULTCS

01 March 2022

Winners of Two 2022 IULTCS Young Leather Scientist Grants for Research Announced

The Executive Committee of the IULTCS is pleased to announce the winners of the 2022 IUR research grants to be awarded to two young scientists, under the age of 35. The monetary awards help support the work of young talent in the leather sector.

This is the eighth year of the grants which have been generously supported by industry and IULTCS alike. The Selection Committee of the IULTCS Research Commission (IUR), chaired by Dr Michael Meyer, is pleased to announce the following recipients:

Young Leather Scientist Grant 2022 Basic Research

Fitsum Etefa Ahmed from the Ethiopian Institute of Textile and Fashion Technology. IULTCS has provided the monetary sponsorship for a single sum of €1,500 grant to Basic Research. The title of the project is ‘Study of anti-ectoparasitic activity of medicinal plant extracts in terms of reducing cockle damage on sheep and goat skin’.

Dr Mike Redwood Young Leather Scientist Grant 2022 Sustainability / Environmental Award

Louret Atsenga Andalo, from Dedan Kimathi University of Technology, Kenya will be the beneficiary of the generosity of Leather Naturally who have sponsored the €1,000 grant for the project entitled ‘Extraction of natural dye (batalain) from beetroot peel (Beta Vulgaris) and application in leather dyeing using bio-mordant’.

Louret Atsenga Andalo

The grants have been very successful and well received by industry. Referring to the awardees of the 2021 grants Dr Meyer said “We are very happy that the research results of last year’s two awardees were presented at the perfectly organised IULTCS Congress in Addis Ababa, Ethiopia last November. Although the number of physical participants was limited, due to the pandemic, we had the chance to attend the remote presentations delivered by Dr Caroline Agustini (Brazil) and Dr Nilay Ork (Turkey).

This year we again received some strong new proposals and two of them have been selected. We look forward to seeing the research outcomes from Fitsum and Louret of the projects we are supporting and wish them every success as they contribute to expanding our industry knowledge.”

The two proposals can be downloaded from the IULTCS website. IUR Research Commission > IULTCS

It is also the opportunity to announce the next call for applications for YLSG 2023. The submission deadline of the next round is 30 November 2022. Details of the eligibility requirements and application forms will be available on the IULTCS website (www.iultcs.org) in May. The IULTCS requests that readers of this announcement forward the information to those institutions and individuals who could benefit from the award.

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