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PRACTICALLY COMPARISON OF SOME MECHANICAL STANDARD TEST METHODS FOR LEATHER AND TEXTILE

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Keywords
Leather,
Fabric,
Artificial Material,
Mechanical Properties,
Standards.

Abstract
Fabrics, leathers and artificial materials show structurally different properties. For example, if a fabric material is woven, it is formed by connecting the threads at a right angle to each other with a certain system; on the other hand, leather is formed by naturally binding complex collagen fibers with specific and different angles depending on their area. Also, artificial materials are produced disparately using PVC and PU. These structural differences directly affect the mechanical properties of materials and therefore Turkish Standards Institute (TSE) offers different test methods for textile and leather materials. There are some differences between these standards according to the shape/size of test samples, jaw length, speed, etc. Since leather is an expensive material and has a limited area, sample sizes of leather standards are smaller than the dimensions specified in the textile standard; however, sample sizes in textile standards can be a problem for some expensive textile materials e.g., silk, silver-added fabrics, vicuna, etc. The aim of this study is to examine the differences between the results obtained from the textile and leather standard methods. In this scope, the tensile strength, elongation and tear load values of the two different tanned garment leathers, artificial material, and two different kinds of woven fabrics were obtained by applying both leather and textile standard methods. While there was a statistical difference between the two methods in tensile strength and elongation values for all materials, no difference was observed in tear load values.

BAZI MEKANIKSEL DERI VE TEKSTIL STANDART METOTLARININ UYGULAMALI OLARAK KARŞILAŞTIRILMASI

Anahtar Kelimeler
Deri,
Kumaş,
Suni Malzeme,
Mekaniksel Özellikler,
Standartlar.

Öz
Kumaşlar, deriler ve suni malzemeler yapısal bakımdan farklı özellikler göstermektedirler. Örneğin kumaş materyali eğer dokumaysa ipliklerin belli bir sistemle birbirlerine dik bir açı ile bağlanmasıyla oluşmakta, diğer bir yandan deri ise tamamen doğal olarak kompleks kolajen liflerinin kendilerine özgü ve alanına bağlı olarak farklı açılar ile bağlanmasıyla oluşmaktadır. Ayrıca suni malzemeler ise tamamen farklı olarak PVC ve PU kullanılarak üretilmektedirler. Bu yapısal farklılıklar özellikle mukavemet özelliklerine doğrudan etki etmektedir ve bu nedenle Türk Standartları Enstitüsü (TSE) tekstil ve deri malzemeler için farklı test yöntemleri sunmaktadır. Bu standartlar arasında test numunelerinin şekli/boyutu, çene aralığı, hızı vb. farklılıklar mevcuttur. Derinin pahalı ve sınırlı bir alana sahip olması nedeniyle deri standartlarının numune boyutları tekstil standardında belirtilen boyutlardan daha küçüktür ancak tekstil standartlarındaki numune boyutları ipek, gümüş katkılı kumaşlar, vicuna vb. pahalı tekstil malzemeleri için sorun olabilmektedir. Bu çalışmanın amacı, tekstil ve deri standart yöntemlerinden elde edilen sonuçlar arasındaki farklılıkları incelemektir. Çalışma kapsamında, hem deri hem de tekstil standart metotları uygulanarak iki farklı tabaklanmış giysilik derinin, bir suni malzemenin ve iki farklı dokuma kumaşın çekme mukavemeti, uzama değerleri ve yırtılma yükü değerleri elde edilmiştir. Çekme mukavemeti ve uzama değerlerinde iki metot arasında tüm materyallerde istatistiki olarak fark çıkarken, yırtılma yükü değerlerinde fark gözlemlenmemiştir.

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Highlights

- Textile materials with different structures such as leathers, fabrics and artificial material were selected.
- Some mechanical test values of these materials were obtained by applying both leather and textile standard methods.
- It was investigated statistically whether there was a significant difference between mentioned standard methods.
- The question was asked whether leather standards can be used instead of textile standards in the testing of fabrics.

Purpose and Scope

Since leather is an expensive material and has a limited area, sample sizes of leather standards are smaller than the dimensions specified in the textile standard; however, sample sizes in textile standards can be a problem for some expensive textile materials e.g., silk, silver-added fabrics, vicuna, etc. The aim of this study is to examine the differences between the results obtained from the textile and leather standard methods.

Design/methodology/approach

The tensile strength, elongation and tear load values of the two different tanned garment leathers, artificial material, and two different kinds of woven fabrics were obtained by applying both leather and textile standard methods. Statistical analyses of the data are obtained by using IBM SPSS Statistics 20 Program. Mann-Whitney U test was performed for testing the significance of the difference between leather and textile standard test methods for each test and each material.

Findings

When the leather and textile standard test methods were compared for tensile strength and elongation values, it is seen that the two standards did not give similar results for all materials. The biggest differences between these two standard test methods are sample sizes and gauge length and for these reasons, it was expected that the results were different.

When the leather standard method, which has a lower gauge length (50 mm) compared to the textile standard method (200 mm), was applied, it was seen that the tensile strength and elongation values of all materials were high.

Tear load results were very close for all materials numerically.

When the physical test results of two standard methods are compared for all materials separately as statistically, it is found that tensile strength and elongation test results differed for all materials between test standard methods. However, it is observed that there are parallel results with numerical data, there are no differences between textile and leather test standard method of tear load for all materials.

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Practical implications
When measuring the tensile strength and elongation values of expensive textile materials, the leather standard method cannot be applied so that testing cannot be done with smaller-sized samples, because the values are higher than the textile standard. When measuring tear load values of expensive textile materials, the leather standard method can be applied thus, fabric consumption can be reduced.

Originality
It has been seen that there is no study in the literature comparing leather and textile standard test methods differently. For this reason, this study provides an original and useful contribution to the literature, but also in future studies, different test methods can be compared using different kind of materials.

1. Introduction

Geometrically, the fabric is a surface with covering properties and it is an elastic material mechanically. The properties of the fabric are largely provided by the unique qualities of the fibers, which are the building blocks of the fabric, and the yarns formed by combining the fibers (Gurkan Unal and Taskin, 2007). A piece of woven cloth consists of two sets of parallel yarns, called the warp and the weft, running perpendicular to each other. As the weft yarns travel through the weave, if they alternately cross over and then under the warp yarns (Breen et al., 1992).

Fabrics construction signifies the adjustment of fabric construction parameters for the subject of project requests for a particular fabric application area. The fabrics construction and its structure respectively are defined by fiber structure and its properties (fiber type; fiber mixture; geometrical, physical, mechanical and chemical properties); yarn structure and its properties (yarn type; geometrical, physical, mechanical and structural properties; technological parameters of spinning); fabric geometry (density, weight, physical, mechanical fabric properties); fabric patterning; technology of fabrics production. Those fabrics structure parameters, which can be numerically evaluated, are important for the announcement of the properties of a new fabric (Sujica and Pinteric, 1998).

Although fabric always comes to mind as a textile material, finished leathers used in leather apparel companies which have an important place in Türkiye and in the world are counted in this category. However, the fabric and leather show different characteristics. One of the biggest differences is that the leather does not have a homogeneous structure like fabric (Ork Efendioglu et al., 2019).

The skin comprises mainly collagen, water, keratin, non-collagenous proteins, poly-saccharides and fats. The strength of the skin is provided by the fiber weave. This is mainly collagen, formed by long chains of amino acids held together by peptide links, and spiralling as a triple helix (Daniels and Landmann,2006). The three-dimensional interweaving of collagen fiber bundles is responsible for its characteristic mechanical properties (Thanikaivelan et al., 2006) which are important characteristics of sheep nappa leathers and influence their end-use and comfort. The construction of garments from leather involves techniques that are similar to those used for garments made from woven fabrics. However, leather differs from textiles primarily because of the nature of the interwoven three-dimensional collagen networks (Phebe et al., 2011). Leather manufacturing involves operations like soaking (rehydration), dehairing, liming, deliming, degreasing, pickling, tanning, post-tanning and finishing processes. The tanning process comprises the conversion of putrefiable skins/hides to a nonputrescible and durable materials (Bienkiewicz, 1983; Kanth et al., 2009; Onem, 2018).

Tanning is the major step in leather production giving strength by the addition of cross-links to the collagen and providing thermal, enzymatic and microbial stability (Fathima et al., 2003). Among the tanning agents, chromium (III) salts are the most extensively used compounds due to the quality and high stabilization ability they impart to leather (Covington, 2008). Another widely used tanning agent is vegetable tannins, especially in the production of natural leathers. Their use is known for centuries, and the mechanism of their stabilization is based on multi-hydrogen links between the polyphenols and collagen (Madhan et al., 2007; Onem et al., 2017). Leather processes and mostly used chemicals have some important effects in the designation of final leather characteristics, however the most important effects are the type of the raw material, type and amount of tanning material used (Ork et al., 2014).

The leather garment industry differs from the woven fabric industry at many different phenomena. Differentiation seems in raw materials features such as size, thickness, biological, chemical or physical homogeneity (Utkun and Ondogan, 2011). The variety of raw materials in the leather industry is not as vast as in the textile industry; however, together with the help of developing technology and innovations in manufacturing, many more new leathers with different and distinctive features are allowed to be produced (Ork et al., 2017). The important basic mechanical properties of leather clothing include even thickness, breaking tension, breaking force and area stretching, whereas the usage specifics refer to permeability to air and water vapor, washing and dry-cleaning characteristics, color stability, resistance to repeated folding (flexing), finish adhesion, and heat and cold resistance (Urbanija and Gersak, 2004).

In recent years, the production of artificial materials, which are alternatives to leather, is popular in markets. Synthetic alternatives usually consist of textile support covered by two or more synthetic polymer layers. Nowadays, often polyester textiles coated by PVC or polyurethane films are used, making them a completely fossil-based material. The surface optic can be designed leather-like by embossing a grain structure. Many different terms are used to describe these materials in the market, e.g., artificial leather, synthetic leather, leatherette, imitation leather, faux leather, man-made leather, bonded leather, pleather, textile leather, or polyurethane (PU)-leather. Meanwhile, the usage of these terms is restricted in the European standard EN 15987 (Meyer et al., 2021). However, as it is known they are synthetic and not healthy as leather which has breathability, air, vapor permeability features and surface properties are also not long-lasting.

It is seen that the mechanical property measurement standards of these materials, which are very different in terms of their structural properties, also naturally differ among themselves. There are some test standards written by Turkish Standards Institution (TSE) to measure the mechanical properties. The most used of these are the tensile strength, elongation percentage and tear load tests. Although garment leathers and fabrics are used in cloth manufacturing, the mechanical standards are differing for leather and textile materials. One of the most important differences is the sample sizing of the standards. For these tests, the sampling sizes specified in the textile standards are quite large when compared to the leather standards.

This study aims to examine the differences between the results obtained from the textile and leather standard methods. In this study, tensile strength, elongation (%) and tear load values of two different tanned garment leathers, artificial material, and two different kinds of fabrics were obtained by applying the standards for both leather and textile. Thus, it was investigated whether there was a significant difference between mentioned mechanical test standard methods.

2. Material and Method

2.1. Materials

Since different materials are desired to be used, two different kinds of leathers, one artificial material and two different kinds of woven fabrics were selected. The dimensional and structural properties of all materials are summarized in Table 1.

Table 1. Materials properties

CODE	MATERIAL	COMPOSITION	THICKNESS (mm)	MASS PER UNIT AREA (g/m2)	ENDS/CM
1	Garment Leather	Chromium Tanned, Sheep	0.56 ± 0.03	353.33 ± 16.55	-
2	Garment Leather	Vegetable Tanned, Sheep	0.90 ± 0.04	456.30 ± 27.80	-
3	Artificial Material	Phthalate-containing polyester	0.51 ± 0.02	484.73 ± 6.84	-
4	Woven Plain Weave Fabric	60% Cotton + 40% Polyacrylonitrile	0.44 ± 0.01	239.50 ± 4.07	Weft: 26 Warp: 29
5	Woven Satin Fabric	100% Polyester	0.17 ± 0.01	108.54 ± 2.13	Weft: 34 Warp: 80

2.2. Methods

2.2.1. Textile Test Methods

Samplings for all tests were subjected according to TS EN 12751 standard (Figure 1). Conditioning parameters were set according to TS EN ISO 139, at 20 ± 2°C temperature and 60% ± 4 relative humidity for 24 hours. The thicknesses of the material samples were measured according to TS 7128 EN ISO 5084 standard by using SDL Atlas thickness gauge.

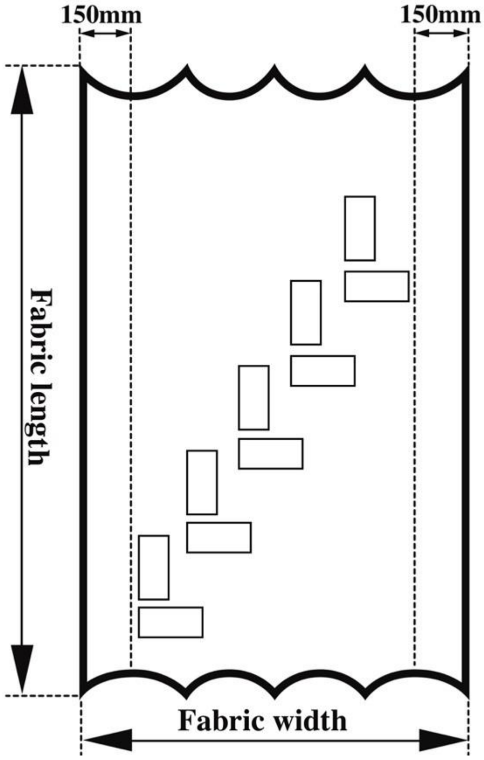

Figure 1. Textiles - sampling locations

Tensile strength and percentage of elongation (TS EN ISO 13934-1):
Two sets of test pieces, 5 parallel in the warp and weft directions, were cut from the fabric sample to be tested (Figure 2). The test sample was placed between the jaws of the test device Zwick/Roell (Figure 3) with a load cell capacity of 2.5 kN. The tensile speed of the device was adjusted to the value specified in the standard depending on the elongation rate of the fabric under force and the test was started. When the test sample ruptured, the maximum force and the amount of elongation under the highest force were recorded in millimetres or %. Tensile strength and modulus were calculated by Equation 1.

$$\text{Tensile strength}, \sigma = \frac{Force}{Area} \quad (1)$$

Here, force and area represent the maximum load to the sample (N) and the cross-sectional area of the sample (mm^2), respectively.

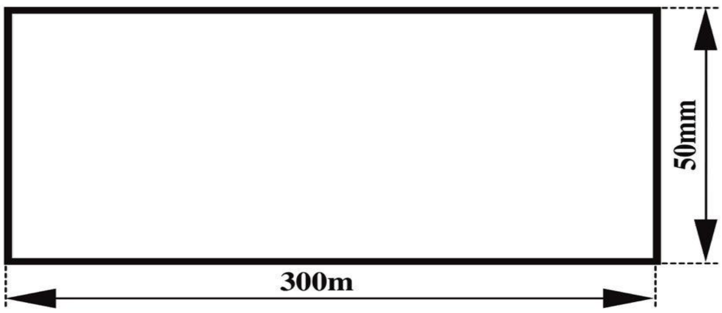

Figure 2. Textiles - sample sizes and shapes in the tensile strength and percentage of elongation test

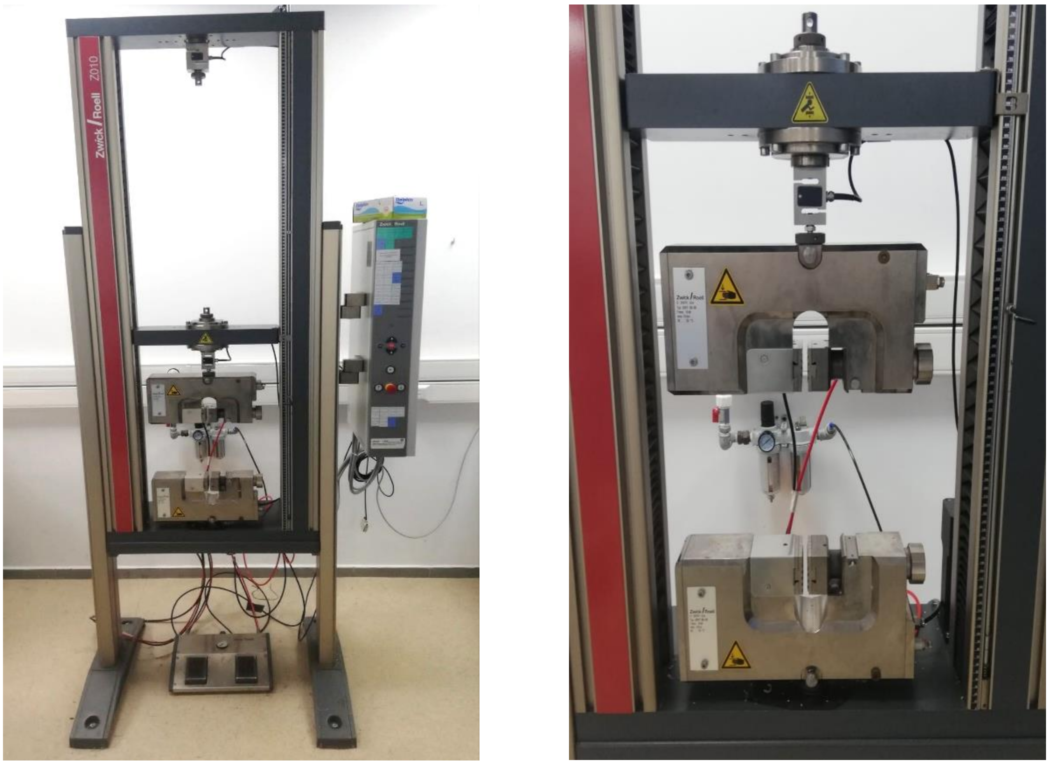

Figure 3. Zwick/Roell tensile tester

Tear load (TS EN ISO 13937-2):

It is based on the principle of determining the force required to advance the tear by pulling the prepared rectangular samples (5 parallel in the warp and weft directions) of 200 x 50 mm dimensions (Figure 4), cut to form a trouser shape in the middle of the short side, by pulling them to form a tear in the device Zwick/Roell (Figure 3) with a load cell capacity of 2.5 kN. The samples were placed in such a way that the notch on the sample comes to the midpoint of the jaw and each of the legs of the trouser-shaped test sample was held by a jaw. The gauge of the device was set to 100 mm and the sample elongation rate was set to 100 mm/sec. The tearing process continued until reaching to the point that marked as 25 mm. When the marked point was reached, the test was stopped and the tearing force was recorded. The average of the maximum and minimum peaks was recorded automatically in the graph created on the computer.

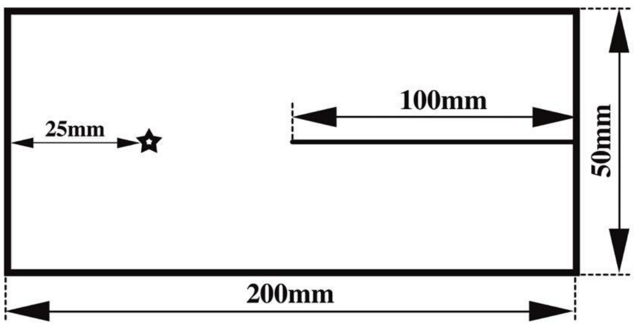

Figure 4. Textiles - sample sizes and shapes in the tear load test

2.2.2. Leather Test Methods

Leather is not a uniform material from a structural perspective. The physical properties of leather change depending on the animal type and the animal individually. Furthermore, these properties exhibit variations in different parts over the leather area (Mutlu et al., 2014). Thus, sampling is important for all leather test methods. TS EN ISO 2418 standard was used for sampling leather materials (Figure 5). Conditioning parameters were set according to TS EN ISO 2419, at 23 ± 2°C temperature and 50% ± 5 relative humidity for 48 hours. The thicknesses of the material samples were measured according to TS EN ISO 2589 standard by using Satra thickness gauge.

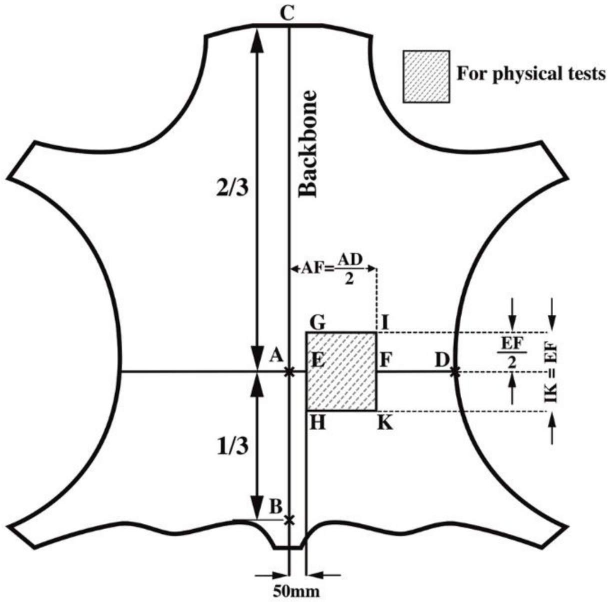

Figure 5. Leathers - sampling locations

Tensile strength and percentage of elongation (TS EN ISO 3376):
The leather test specimen (Figure 6) was clamped in the jaws of Shimadzu AG-IS Tensile Tester (Figure 7) with a load cell capacity of 5 kN. The test was performed in 3 set (3 parallel and 3 perpendiculars to the backbone). The separation speed of the device's jaws was set at 100 ± 20 mm/min. The device was operated until the test piece broke and the highest measured tensile force was recorded as F, and the tensile strength was recorded as F/mm2 by dividing the highest tensile force by the sample cross-sectional area (Equation 1) and the elongation percentage was recorded as the last length of the sample on tensile.

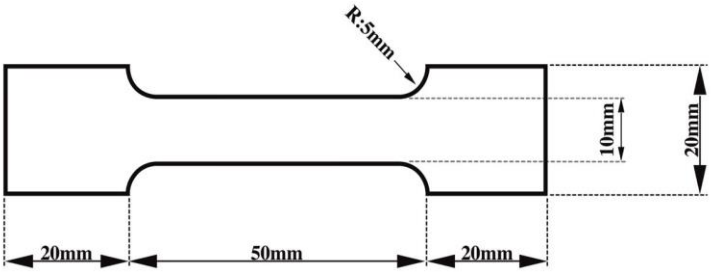

Figure 6. Leathers - sample sizes and shapes in the tensile strength and percentage of elongation test

Figure 7. Shimadzu AG-IS tensile tester

Tear load (TS EN ISO 3377-1):
Samples were cut from the materials to be tested (Figure 8). The test was performed in 3 set (3 parallel and 3 perpendiculars to the backbone). The distance between the jaws of Shimadzu AG-IS Tensile Tester device (Figure 7) with a load cell capacity of 5 kN was set to 50 mm. 20 mm of one leg of the test piece was attached to the lower jaw of the device. The other leg is folded 180° and similarly attached to the other jaw. For the determination of the arithmetic mean of the applied force, the graph consisting of the peaks was divided into four equal parts from the beginning of the first peak to the end of the last peak. The first and last parts were not used in the average value calculation. Two highest and two lowest peaks were selected from each of the other two parts. A suitable peak for the calculation is characterized by a 10% increase and decrease in strength. The tear load of each test sample was calculated based on the arithmetic mean in N from the obtained peak values.

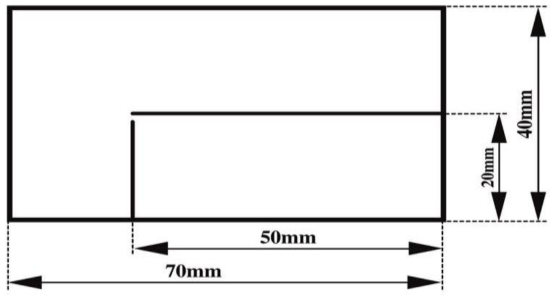

Figure 8. Leathers - sample sizes and shapes in the tear load test

2.2.3. Statistical Method

Statistical analyses of the data are obtained by using IBM SPSS Statistics 20 Program. Mann-Whitney U test was performed for testing the significance of the difference between leather and textile standard test methods for each test and each material.

3. Experimental Results

All five materials were tested for tensile strength, elongation percentage and tear strength by applying both textile and leather standards. The obtained data are given in Table 2 and the values are transferred to the graphs in Figure 9, 10, and 11 for easier visual evaluation.

Tensile strength is one of the most important physical quantities of characterizing the mechanical properties of materials (Case et al., 1999). It is a routine quality control test in the leather industry where maximum stress and breaking elongation of leathers are determined (Kontou and Farasoglou, 1998; Nalbant et al., 2016).

The tensile properties of woven fabrics are significant as they can indicate the fabrics' behavior during wear. In tensile testing, the main parameters include tensile stiffness, tensile stress and tensile strain. A typical tensile stress-strain curve of a woven fabric confirms the nonlinear behavior of the material, which is present in the initial stage during yarns alignment, which results in lower stress increase and in the final stage as the applied force overcomes the frictional force (Šomođi et al., 2019). Elongation at break is the increase in the length of the fabric when it breaks (Balci and Babaarslan, 2005). The breaking force in woven fabrics is measured as the force required for the fabric to break when a tension force is applied to the fabric. It can be said that the higher this tension force, the more durable the fabric is (Gurcum, 2010).

When the leather and textile standard test methods were compared for tensile strength and elongation values, it is seen that the two standards did not give similar results for all materials in Table 2 and Figure 9-10. The biggest differences between these two standard test methods are sample sizes and gauge length and for these reasons, it was expected that the results were different. Thanikaivelan et al., (2006) obtained tensile strength and elongation percentage results of shoe upper leathers by using different gauge lengths in their studies and found that the maximum breaking load and the percentage extension at break decreased with the increase in gauge length. In Figure 9 and 10 it is clearly seen when the leather standard method, which has a lower gauge length (50 mm) compared to the textile standard method (200 mm), was applied, it was seen that the tensile strength and elongation values of all materials were high.

Table 2. Mechanical properties of materials for two standards*

Code		Leather Standards Methods			Textile Standards Methods		
		Perpendicular/ Weft	**Parallel/ Warp**	**Mean**	**Perpendicular/ Weft**	**Parallel/ Warp**	**Mean**
1	Tensile Strength (N/mm^2)	8.16±0.70	10.86±0.79	9.51±1.78	6.06±1.60	6.39±1.71	6.23±1.52
	Elongation (%)	33.08±2.56	60.86±4.41	49.97±10.05	35.57±5.81	45.04±7.19	40.31±6.96
	Tear Load (N)	3.97±0.46	4.94±0.47	4.45±0.48	4.03±1.81	4.48±2.20	4.26±1.73
2	Tensile Strength (N/mm^2)	16.74±3.46	18.05±4.03	17.40±4.75	10.46±1.71	13.34±2.76	12.25±2.04
	Elongation (%)	65.50±9.11	65.39±6.15	65.45±9.87	57.23±11.36	62.43±13.90	59.83±11.64
	Tear Load (N)	10.51±1.19	12.70±1.42	11.61±2.11	9.91±1.07	11.38±1.81	10.65±1.95
3	Tensile Strength (N/mm^2)	9.10±0.28	14.03±0.49	11.56±3.33	6.02±0.41	10.02±0.99	8.02±2.71
	Elongation (%)	74.83±2.11	187.05±4.48	133.46±44.54	73.86±3.42	125.93± 5.55	99.90±33.10
	Tear Load (N)	12.03±1.64	14.08±1.75	13.05±1.71	11.95±0.80	13.74±1.46	12.75±1.94
4	Tensile Strength (N/mm^2)	49.51±2.34	57.93±4.22	53.72±7.64	43.19±3.59	48.47±4.83	45.83±4.75
	Elongation (%)	35.89±1.56	34.41±2.62	35.15±1.81	21.6±1.38	24.93±1.64	23.26±1.46
	Tear Load (N)	126.03±27.20	151.70±28.08	138.86±35.35	124.25±19.38	149.52±25.24	136.88±27.03
5	Tensile Strength (N/mm^2)	84.77±10.97	164.14±20.39	124.46±34.34	67.01±8.08	140.64±13.68	103.82±35.48
	Elongation (%)	38.19±3.31	44.87±5.68	41.53±5.01	23.00±2.97	28.14±3.00	25.57±3.72
	Tear Load (N)	24.95±2.01	38.36±6.13	31.65±7.61	23.24±1.11	35.20±2.31	29.22±4.01

* Tear load results: Weft direction means weft tear load value on warp direction and warp direction means warp tear load value on weft direction.

Tear strength is the resisting force required to initiate, sustain or propagate a tear under certain conditions. Tear strength is an important factor that determines the strength of the material against the static and dynamic forces on the fabric and against the tension applied in the tear test. During tearing, the yarns break one by one or form groups (Ozdil and Ozcelik, 2006). The single edge tear test gives information about the mechanical strength of the leathers in the case of an applied force on a created tear on leather (Nalbant et al., 2016).

When Table 2 was examined for tear load results, it can be seen that the values are very close for all materials numerically. This phenomenon is already visible in Figure 11.

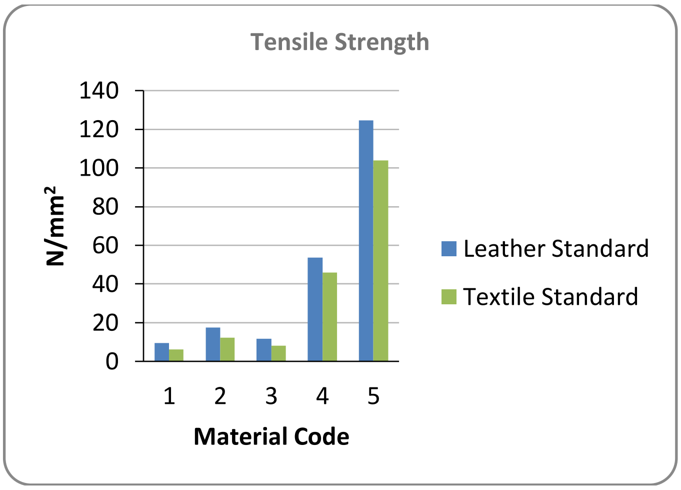

Figure 9. Tensile strength values for leather and textile test standard methods

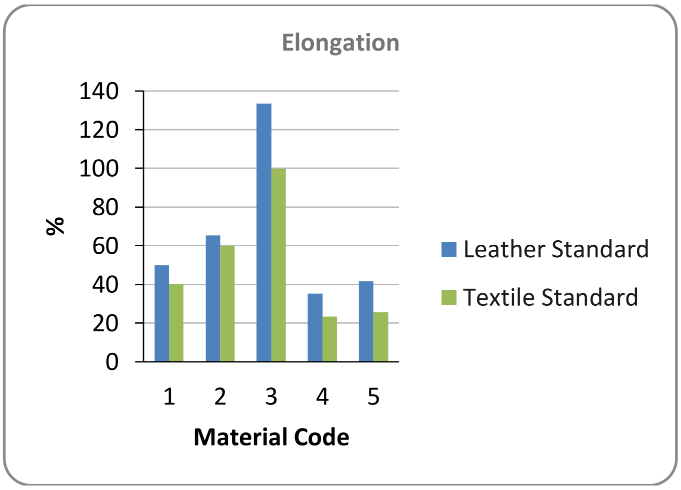

Figure 10. Elongation values for leather and textile test standard methods

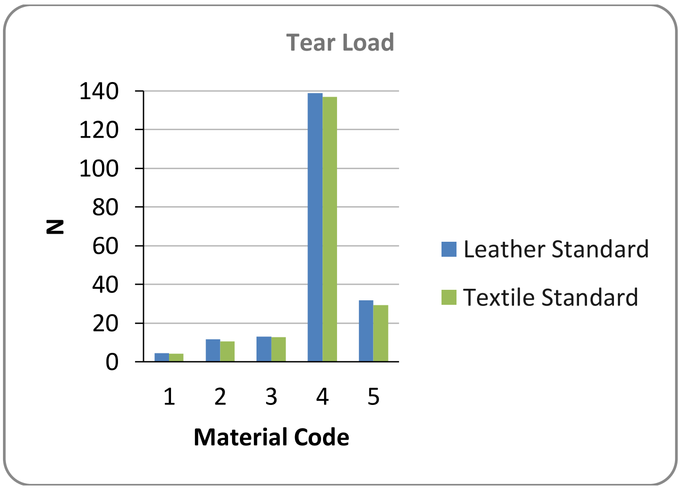

Figure 11. Tear load values for leather and textile test standard methods

In Table 3, when the physical test results of two standard methods are compared for all materials separately as statistically, it is found that tensile strength and elongation test results differed for all materials between test standard methods. However, it is observed that there are parallel results with numerical data, there are no differences between textile and leather test standard method of tear load for all materials.

Table 3. Statistical comparisons of two standard methods*

Code	Tensile Strength (N/mm2)	Elongation (%)	Tear Load (N)
1	0.044 Diff.	0.045 Diff.	0.195 No diff.
2	0.041 Diff.	0.044 Diff.	0.052 No diff.
3	0.023 Diff.	0.021 Diff.	0.096 No diff.
4	0.045 Diff.	0.000 Diff.	0.142 No diff.
5	0.022 Diff.	0.000 Diff.	0.133 No diff.

*(p<0.05)

4. Result and Discussion

Tensile strength, elongation and tear load tests provide the most used values to describe a material mechanically. It is known that these tests apply different standard methods according to the materials. Considering that woven fabrics consist of weft-warp structures, leather is a combination of collagen fiber bundles and artificial material has a nonwoven structure, these materials are similar to each other but also have very different structural properties.

In this study, two different standard test methods prepared for the materials with these different properties were compared with each other and the following results were obtained:

- The tensile strength, elongation and tear load values of parallel/warp samples were higher for all materials than perpendicular/weft samples.

- In the tensile strength and elongation test results obtained from the leather standard test method were found to be higher than the textile standard test method. The reasons for this can be explained as, when the jaw length was short, probability of coincidence of the deformation area of the material was decrease, thereby increasing the strength value. In addition, the high-strength part of the leather, which is suitable for testing, is located in a small area. When the samples are taken according to the textile standard, the coinciding of the weak places with the sample reduces the strength results. It can be said that due to the nature of the leather, it is less homogeneous than the textile material and the regional strength changes are higher. For this reason, the probability of finding a weak place in the sample increases in the strength measurement for a larger sample.

- Statistically, the difference between the two methods was observed on tensile strength and elongation test results. When measuring the tensile strength and elongation values of expensive textile materials, the leather standard method cannot be applied so that testing cannot be done with smaller-sized samples, because the values are higher than the textile standard.

- Considering the tear load values, no statistical difference was observed between the leather and textile standard test methods for all materials. Because the distance between the jaws does not make much sense in tearing. It only changes the number of torn ends down, that is, the average number of torn ends down increases and more reliable results are obtained, but there is no expectation that it will be higher or lower. Furthermore, when measuring tear load values of expensive textile materials, the leather standard method can be applied thus, fabric consumption can be reduced.

It has been seen that there is no study in the literature comparing leather and textile standard test methods differently. For this reason, this study provides an original and useful contribution to the literature, but also in future studies, different test methods can be compared using different kind of materials.

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Conflict of Interest

No conflict of interest was declared by the authors.

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