COMPARISON OF WATER PERMEABILITY AND WATER ABSORPTION PERFORMANCE OF SHOE UPPER LEATHERS

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Abstract: *Today, leather footwear is preferred for the comfort, convenience, and durability properties. In addition to these features, it is expected to have high water performance especially in winter and outdoor leather shoes. For this purpose, in the present study twenty–one shoe upper leathers differentiated in finishing techniques (finished, printed and patent) were investigated in terms of water performance tests such as dynamic water absorption/penetrometer (TS EN ISO 5403-1), static water absorption (TS EN ISO 2417) and water vapor permeability (TS EN ISO 14268). The upper leather samples, collected from different leather manufacturing plants in Turkey, were prepared and conditioned according to TS EN ISO 2419 standard prior to tests. The results revealed that patent leathers gave the highest penetrometer values compared to finished and printed shoe upper leathers. Besides, finished, and printed shoe upper leathers provided the highest water vapour permeability values compared to patent leathers. As a result, the sample of R gave a water vapor permeability value of 7500 mg/cm^2.h along with the best penetrometer and static water absorption results. As a conclusion, the results obtained from the study would help in improving the quality standards of shoe upper leathers in terms of water performance tests and could show the current situation in the production of shoe upper leathers.*

Key words: *Upper leather, finishing techniques, water vapour permeability, water absorption, penetrometer*

1. INTRODUCTION

Leather has been used since centuries to protect the bodies of human beings from external conditions. In particular, footwear has developed and designed to wrap the feet of human being and itimproves the walking characteristics and is the indicator of the people’s social status [1]. Today it is well known that upper leathers are used in footwear manufacturing as a main material considering the spent of time in a footwear. They have positive effects on foot health and comfort and are produced by using different types of leather depending on the usage purposes. In addition, upper leathers form the upper surface of the footwear and they are manufactured with different production methods which give different properties and functions [2].

The quality of shoe upper leather is generally evaluated by its behavior towards water rather than the external appearance. The water resistance of the upper leather is an important feature for footwears that are comfortable to wear even in wet and cold conditions [3,4]. It is especially important for the winter leather footwears to pass the water performance tests for the comfort of the wear material. Herrmann, 2006, indicated the usage requirements of the waterproof leathers such as no water penetration, controllable water up-take, high water vapor permeability, heat and cold insulation, lightweight, wearing comfort and second breathing skin [5]. Also, the testing requirements are explained by Herrmann by water droplet test, static water up-take (absorption), soaking-up test (wicking-test), bally penetrometer, maeser and water vapor permeability [5].

In the present study, the effect of different finishing techniques on the water performance properties of the shoe upper leathers were investigated by determination of water vapor permeability, static (kubelka) and dynamic (penetrometer) water absorption properties. For this purpose, twenty-one shoe upper leathers obtained from various producers were collected and separated into three groups depending on the finishing types of the leathers in order to test the water performance properties.

2. MATERIALS AND METHODS

2.1 Materials

In this study, twenty-one upper leathers (UL) finished with different techniques were used as a material. They were collected from different upper leather manufacturers oriented in İzmir, İstanbul and Bursa. Each upper leather sample was entitled as follows (Table 1) and the finishing techniques and the classification of the upper leathers were given in Table 1 and Table 2 respectively.

Table 1. *Upper leathers used in the study*

Upper leathers		
(A): Finished leather	**(H):** Printed leather	**(O):** Printed leather
(B): Soft matte patent leather	**(I):** Matte patent leather	**(P):** Printed leather
(C): Finished leather	**(J):** Patent leather	**(R):** Printed leather
(D): Suede rustic finished leather	**(K):** Waxed matte patent leather	**(T):** Soft finished leather
(E): Printed leather	**(L):** Printed leather	**(U):** Finished leather
(F): Matte patent leather	**(M):** Printed patent leather	**(V):** Finished leather
(G): Patent leather	**(N):** Printed nacreous patent leather	**(Y):** Printed leather

Table 2. *Classification of the upper leathers*

Groups	Finishing type	Sample codes
I	Finished leathers	A-C-D-I-T-U-V (7 pieces)
II	Patent leathers	B-F-G-J-K-M-N (7 pieces)
III	Printed leathers	E-H-L-O-P-R-Y (7 pieces)

2.2 Methods

Upper leathers finished with different techniques were prepared and conditioned in accordance with physical and mechanical tests-sample preparation and conditioning standard (TS EN ISO 2419) [6] prior to tests. After conditioning of the upper leathers, penetrometer (TS EN ISO 5403-1) [7], static water absorption (TS EN ISO 2417) [8], and water vapor permeability (TS EN ISO 14268) [9] were performed to determine the behaviour of the upper leathers against water.

3. RESULTS AND DISCUSSION

3.1. Performance Values of Group I

The physical characteristics of the upper leathers classified as group I are given in Table 3.

Table 3. *Physical test results of the upper leathers belongs to group I*

Samples	Thickness values (mm)	Water vapour permeability (mg/cm^2.h)	Static water absorption (24h/ml/100g)	Penetrometer (Water absorption %)	Penetrometer time (min)
A	1.29	1.87±0.08	194.93	8.80	123
C	1.47	5.24±0.14	130.04	4.47	5
D	0.88	5.87±0.59	101.18	22.56	7
I	1.00	5.65±0.08	221.32	21.20	1
T	0.97	14.10±0.53	253.27	28.94	1
U	1.69	14.01±0.88	112.21	8.78	35
V	1.17	4.47±0.30	94.38	5.21	22

The upper leather entitled as A gave the highest penetrometer test results with 123 minutes and 8.80% water absorption. These results indicated that the upper leather A met the requirement of waterproof upper leathers [10,11]. Besides, the penetrometer test results of U and V were found above 20 minutes with less than 30% water absorption that shows the requirement of water performance standards of upper leathers was provided [10,11].

The static water absorption values of the upper leathers in Group I was found higher than the recommended value given for upper leathers (<85 ml/100 g). Although the upper leather entitled as A has the highest penetrometer value, the static water absorption value of the leather was found as 194.93 ml/100gr which was higher than the standard recommended value in terms of physical testing [10,11].

The finished leathers provided the expected values of WVP from upper leathers according to the standards [10,11]. The lowest WVP value was obtained from the sample of A due to the wet-end and finishing techniques of the upper leathers. The leathers C, D, I and V had similar WVP results although they were processed in different plants in addition to the similar results obtained from T and U leathers. The WVP results of the study were found higher than the results of Kanli et al., 2010 (1.36 and 1.95 mg/cm^2.h for pigmented box and calf leathers) [12] and similar with Adiguzel Zengin et al., 2017 (4 mg/cm^2.h and 10 mg/cm^2.h pigmented calf leathers respectively).

3.2. Performance Values of Group II

The results of the upper leathers classified as group II (patent leathers) are given in Table 4.

Table 4. *Physical test results of the upper leathers belongs to group II*

Samples	Thickness values (mm)	Water vapour permability (mg/cm^2.h)	Static water absorption (24h/ml/100g)	Penetrometer (Water absorption %)	Penetrometer time (min)
B	0.87	0.44±0.05	173.32	11.11	96
F	0.89	1.06±0.06	113.23	11.92	150
G	1.25	0.43±0.06	132.10	6.67	83
J	1.25	0.24±0.00	92.91	10.40	113
K	0.78	0.21±0,001	155.55	9.10	205
M	0.81	0.63±0.08	190.19	14.05	135
N	1.01	0.16±0.00	161.05	10.90	27

Patent leathers have higher performance in terms of penetrometer test results compared to Group I and II. All group samples gave higher penetrometer values than 20 minutes as expected from upper leathers. Besides, the penetrometer water absorption results (%) were determined under 30% maximum water absorption value which is the limitation for the corrected grain upper leathers [10,11]. Additionaly, the samples of F, K and M fulfilled the requirement of IUP 10 prepared for the waterproof upper leathers (120 minutes, 25% water absorption) [11]. The sample K provided the highest value of penetrometer test among all the upper leather samples by determination of 9% water absorption at 205 minutes.

Although the patent leathers in group II fulfil the criteria of penetrometer test, they did not provide the minimum standard value of static water absorption for the corrected grain upper leathers. The static water absorption values of patent leathers were determined above the standard value of 85ml/100gr given in literature [10,11]. Only the sample J (92.91ml/100g) had the closest value to the standard among the patent leather samples.

The water vapor permeability values of the patent leathers were found lower than the group I and II due to the finishing technique applied to leathers. Adiguzel Zengin et al., 2017 were found similar WVP results for the patent leathers among the values of 0.2 and 0.4 mg/cm^{2}h for goat and calf leathers, respectively. But the results of Kanli et al., 2010 were determined higher than the study with the values of 1.14 ± 0.32 and 1.68 ± 0.98 for the calf and goat leathers [12].

3.3. Performance Values of Group III

The results of the upper leathers classified as group III are given in Table 5.

Table 5. *Physical test results of the upper leathers belongs to group III*

Samples	Thickness values (mm)	Water vapour permability (mg/cm^2.h)	Static water absorption (24h/ml/100g)	Penetrometer (Water absorption %)	Penetrometer time (min)
E	2.32	0.54±0.06	117.48	16.94	136
H	0.72	15.37±1.07	323.33	20.84	1
L	2.50	0.85±0.03	200.25	4.74	21
O	0.99	7.27±0.91	141.57	17.00	4
P	1.44	11.13±1.53	177.38	27.62	3
R	2.5	1.61±0.02	38.39	4.87	136
Y	0.97	5.92±0.45	230.23	13.21	4

The penetrometer test values of printed upper leathers found similar to Group I. Only the samples of E and R provided higher penetrometer results (136 minutes) in comparison with the standard value [10,11] and met the IUP10 standard value [11]. The water absorption (%) values of the penetrometer test were found between approximately 28% and 5%. The sample of R gave one of the highest penetrometer test results with the minimum water absorption among all groups.

When the static water absorption values of the printed leathers were examined at 24 hours, it was determined that the static water absorption values of the samples except the sample of R were found to be quite high. With a value of 38.39ml/100g, the R sample gave the best result among all upper leather samples. Besides, it can be revealed that the sample of R had the highest performance in terms of dynamic and static water absorption values.

The sample of H had the highest water vapor permeability with a value of nearly 15.37±1.07mg/cm^{2}h compared to all upper leathers. The sample of E has the lowest water vapor permeability with 0.54±0.06 mg/cm^{2}h in Group III. This could be due to the difference in thickness values of the leathers as well as the thickness of the finishing coats. Because Śmiechowski et al., 2014 mentioned the importance of the finishing coats thickness especially for thick leathers, although leather thickness was one of the most precious parameters on water vapor permeability [13].

Consequently, the upper leathers entitled as A, K and R gave the best penetrometer results among the groups (Figure 1). They were differentiated in finishing techniques and the sample of K, belongs to the patent leathers group, showed the best penetrometer result among the upper leathers.

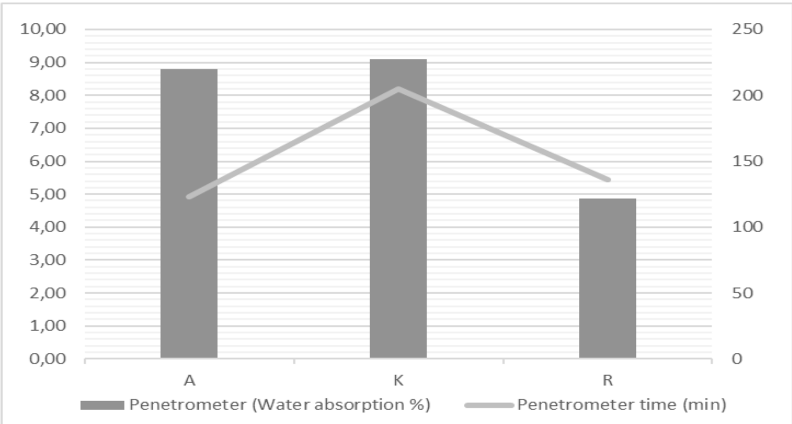

Fig. 1. *The penetrometer results of the upper leathers entitled as A, K and R*

As expected, the water vapor permeability of patent leathers (N) are found lower than printed and finished (T) leathers. However, the static water absorption of printed leather (H) had the highest value compared to other groups. This could be due to the type of the finishing technique, products as well as the wet-end operations that is applied.

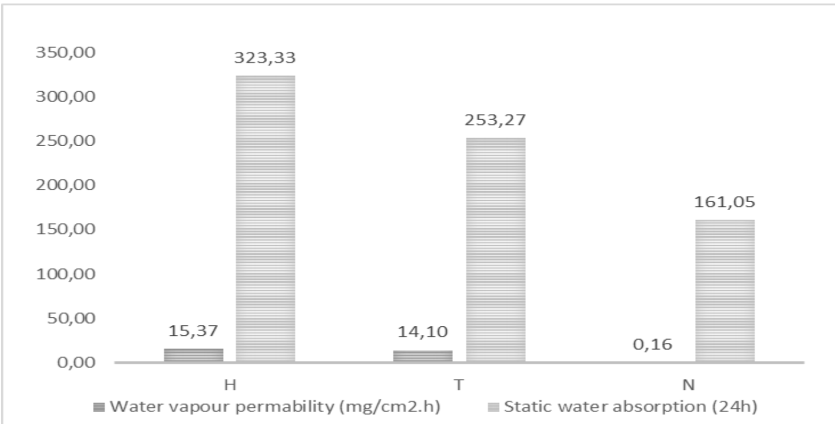

Fig. 2. *The water vapor permeability and static water absoption results of the upper leathers entitled as H, T and N*

4. CONCLUSIONS

The results obtained from this study show that the performance values of the upper leathers against water varies depending on the type of finishing as well as the production techniques used in the leather industry. Patent leathers gave the highest values of penetrometer test among the groups of finished and printed upper leathers. Finished and printed upper leathers have the highest water vapour permeability test results compared to patent leathers and the diffentiated values of water vapour permeability of these two groups of leathers occurred due to the wet-end and finishing production techniques. These results would help considerably in improving the quality standards of shoe upper leathers produced in leather industry and help to present the current circumstances in the production of the shoe upper leathers.

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REFERENCES

[1] B. O. Bitlisli, A.C. Adıgüzel Zengin, G. Yeldiyar, G. Kairanbekov, and E. Küçükakın, "*Upper leathers in shoe manufacturing*'' Industrial Technology and Engineering, 2013, vol. 2, pp. 37-41.

[2] A.C. Adıgüzel Zengin, N. Oğlakcioglu and B. O. Bitlisli, "*Effect of finishing techniques on some physical characteristics of shoe upper leathers"* Tekstil ve Konfeksiyon 27, 2017, vol. 2, pp. 198-203.

[3] V. Jankauskaitė, J. Indira, G. Ada, Š. Justa, B. Kęstutis, and U. Virginijus, *"Comparable evaluation of leather waterproofing behaviour upon hide quality. I. Influence of retanning and fatliqouring agents on leather structure and properties"* Materials science 18, 2012, vol. 2, pp. 150-157.

[4] Ö. Sarı and A. C. Adiguzel, *"The effects of different liming and tanning processes on waterproofing properties"* I. National Leather Symposium, 7-8 October 2004, Izmir Turkey, pp143-158.

[5] W. Herrmann, *"Waterproof leather-requirements and technology"* Leather International, 2006, vol. 9, pp. 56-58.

[6] TS EN ISO 2419, 2012, Leather-Physical and Mechanical Tests-Sample Preparation and Conditioning, Turkish Standards Institute Necatibey Caddesi No.112, Bakanlıklar / Ankara.

[7] TS EN ISO 5403-1, 2012, Determination of water resistance of flexible leather - Part 1: Repeated linear compression (penetrometer), Turkish Standards Institute Necatibey Caddesi No.112, Bakanlıklar / Ankara.

[8] TS EN ISO 2417, 2016, Physical and mechanical tests - Determination of the static absorption of water, Turkish Standards Institute Necatibey Caddesi No.112, Bakanlıklar / Ankara.

[9] TS EN ISO 14268, 2014, Physical and mechanical tests - Determination of water vapour permeability, Turkish Standards Institute Necatibey Caddesi No.112, Bakanlıklar / Ankara.

[10] Basf, Pocket Book for the Leather Technologist, fourth edition, revised and enlarged, 2007, BASF Aktiengesellschaft 67056 Ludwigshafen, Germany, pp. 242

[11] UNIDO, 1996, Acceptable quality standards in the leather and footwear industry. Vienna, Austria: United Nations Industrial Development Organization.

[12] N. Kanli, A.C. Adıgüzel Zengin, and B. O. Bitlisli, "*The Effects of Different Finishing Types on Water Vapour and Air Permeability Properties of Shoe Upper Leathers*" ICAMS 2010 – 3rd International Conference on Advanced Materials and Systems, 16th to 18th September 2010, Bucharest, Romania, pp63-66.

[13] K. Śmiechowski, J. Żarłok, and M. Kowalska, "*The relationship between water vapor permeability and softness for leathers produced in Poland*", Journal of the Society Leather Technologist and Chemists, 2014 vol. 98, pp. 259-263.