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Level of Comfort: Artificial and Natural Shoe Materials. A Comprehensive Assessment

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Abstract. Hygroscopicity, moisture return, wetting, capillarity and water vapour permeability of materials were studied in shoes linings and insoles made of natural and artificial leather. It was established that liquid-based and final finishing deteriorate hygienic properties of natural leather to a great extend. With the use of obtained results, a new graphically-numerical method was tested in assessment of shoe material comfortability, the materials that have direct contact with the human foot. According to the method, the ratio between pentagon areas of material tested and reference material is taken as quantitative indicator of quality.

Introduction

Healthy competition promotes the production of high quality products, because a market relation model is based on the priorities of consumerisms strategy, which, in its turn, aimed at supporting rights and guarantees of consumers. Quality requirements and measures for its control in the EU member are developing the producers themselves, and the government controls only safe products. However, worth to be mentioned, that with buyers chasing lower prices for manufactured goods there is a steady trend of developing a problem with unfair competition. Not always customers are able to identify articles of proper quality. This problem is especially acute in relation with the depletion and shortage of natural raw materials including natural and synthetic fibers and fibrous materials being traditional raw materials for light industry. Moreover, such factors as world economy agglomeration, liberal requirements to commercial product and informational globalization facilitate the process.

In EU member states, the only mandatory requirement to producers is that they must provide information on the product to the customer, and apply appropriate labeling of the basic materials used. According to the EU Directive No.94/11/EC [1], the following information shall be provided at the labeling of shoe materials: natural leather, natural leather with covering, artificial leather, textile material or synthetic material. It is obvious the above classification of material does not objectively define performance properties of the products, e.g. the level of comfort for customers wearing it. The situation is somewhat better in garment and apparel domain. It is envisaged by the EU Directive No.2008/121/EC [2] that the fibrous composition of material shall be indicated. It is appropriate to mention that consumer qualities of cotton-based fibers, namely viscose, linen, hemp, cotton (petals) are different. Besides, different way of treatment, i.e. hydrophobization, fattening, filling, dyeing, dressing, impregnation, duplication, etc. makes different effect on the level of comfort in use.

On the other hand, the advances in science and technology make contribution to the emergence of alternative materials: artificial and synthetic leathers and fibers being ready available and cheaper, as well as nanofibers and polymers further expanding the assortment of materials. Therefore, based on the key role of the consumer in market relations, the problem of an objective evaluation of the performance properties of the materials that come in direct contact with human body and that may affect feel-good factor, physiological condition and health of a person. That is why the issue of revising existing norms and standards to make them improved and perfect, is always topical. In our opinion, it is advisable to create a new approach in consumer properties evaluation, including level of comfort, of the materials under question, with proper information to provide for.

Practical experience in the technology of nonfoods material indicates that quality requirements to footwear are determined, primarily, by ergonomic and service properties of footwear materials [3].

We analyzed the known methods for quantitative assessment of hygienic properties of shoes and shoe materials, in particular [4]: a graphically-numerical method by A. Blažej, a mathematical method of determining the complex index of hygienic properties by M.N. Ivanov and E.S. Hlayzer, an express-method of shoe comfort by M.N. Ivanov, A.A. Nikolayev, and others. Unfortunately, the methods listed do not allow an objective assessment of footwear and shoe material level of comfort due to the lack of completeness and accuracy of the results, and, sometimes – because of inattentive attitude toward consumers feel-good. As a whole, there was no systematic analysis of personal feel-good under comfortable or non-comfortable conditions related to wearing shoes. Hence, there is a pending necessity to develop a new, more accurate methodology in comprehensive assessment of shoe material hygienic properties. The methodology must take into account two integral components of assessment process, namely: a subjective component reflecting the opinion of experts-carriers of shoes, and an objective one, which is based on the existing standard methods of research.

The feeling of comfort or discomfort in the system «consumer-shoes-environment» is closely connected to environmental conditions and individual characteristics of the consumer, while the dominant process is sweating of human body [5-7].

Based on the foregoing, an expert questioning of the respondents was carried out in order to have a subjective consumer characteristics assessment of shoe materials. It was found [5] that consumer's feelings of discomfort in the «shoe-consumer-environment» system may differ, as they depend on the environmental conditions, type of shoes, nature of materials used and individual features of a person. Analyzing the relations between psychological (organoleptic consumer sensations), physiological (irritants) and physical (environmental conditions) phenomena it was determined the influence of shoes on consumer senses. It was found that the dominant factor in the assessment of ergonomic properties of shoes is human mental comfort or discomfort, which is determined on the basis of respondent's organoleptic perception.

Based on the questionnaire survey of respondents, consumer feeling under discomfort conditions was systematized, and a local sweating of human foot was researched. It was found that, no matter of the comfortable or discomfortable conditions, the major sweating of human foot surface occurs in the toe, beam and shank parts of the foot. This is explained by intensive work of the foot muscles whilst wearing the shoes. The intensity of foot sweating under comfortable conditions (left foot), is 1.2 g/h, and in discomfort conditions the same is 2.24 g/h (right foot). Foot surface temperatures are: a) 30.4-31.3 º C on the back surface, 28.6-29.1 º C – on the running surface of the foot, which was located in discomfort, and b) 27.7-29.5 º C on the back surface, 25.5-27.0 º C – on the working surface of the foot that was exposed to comfortable conditions.

The objective evaluation of consumer properties in shoe materials by means of standard methodology was concentrated on basic hygienic indices of these materials responsible for the foot comfort during the use of shoes: a) hygroscopicity – characterizes sorption capacity of material; b) moisture return characterizes desorption properties of material with respect to water vapour; c) water vapour permeability – describes the ability of material to pass moisture vapour through; d) capillarity – associated with local transmission of physical-mechanical moisture of sweating; e) wetting – characterizes the ability of material to absorb water while in direct contact with wet environment. These parameters were determined by weighing on analytical scales [8]. The obtained experimental data were processed by means of mathematical statistics methods [9]. The study resulted in suggesting a mechanism of moisture exchange, in which the indicators of hygroscopicity → moisture return → water vapour permeability → capillarity → wetting set show the dynamics of changes in moisture content for shoe material under steam-drip sweating.

Experiment

Yu.I. Fordzyun developed a new graphically-numerical method («pentagon»), based on quantitative and graphical approach in order to make a comprehensive assessment of hygienic properties of materials. A specialty of the method is that a reference material having the best performance indicators among the samples is to be selected. As a rule, natural leather would be identified as a standard. Impartial nature of material comfortability assessment is provided by comparative analysis of a set of parameters describing its hygienic properties, i.e. hygroscopicity; moisture return; water vapour permeability; capillarity; wetting. To do that, a central point is allocated in a pentagon, and the figure is divided by triangles in five equal parts. Each cathetus of triangle stands for the highest value of relevant hygienic properties of reference material.

Graphical depicting of the indices enables multi-sided presentation of dynamic changes in moisture content of studied material under steam-drip sweating in comparison to reference material. Again, the pentagon area may be considered as a certain type of measure for hygienic properties of the best shoe material, which is natural leather.

In order to evaluate hygienic properties of any shoe material (natural, artificial or synthetic leather of certain production application), an actual indicator value is scaled according to the value of same indicator for reference material (natural leather). Therefore, the area of resulted pentagon determines the level of hygienic properties of given material.

Table 1. Characteristics and indices of shoe materials

Material	Thickness, mm	Hygro-scopicity, %	Moisture return, %	Wetting, %	Capillarity, cm^2/min	Water vapour permeability, $mg/cm^2 \cdot hour$
Natural lining leather						
Undyed leather made of pigskin	0.50	**13.60**	**10.70**	**149.20**	**3.14**	**0.33**
Dyed leather made of pigskin without covering	0.70	8.70	6.50	87.07	0.39	0.21
Dyed leather made of cattle hides without covering	0.70	9.00	7.65	84.90	0.07	0.16
Dyed leather made of cattle hides with covering	0.60	6.40	5.16	98.96	0.35	0.19
Dyed leather made of horse with covering	0.70	30.08	16.08	82.23	0.07	0.12
Split made of pigskin	0.50	2.90	2.00	88.40	0.27	0.18
Natural insole leather						
Dyed leather made of cattle hides without covering	3.20	5.01	6.30	40.05	0.10	0.09
Dyed leather made of cattle hides with covering	2.50	4.30	4.66	60.90	0.03	0.10
Dyed leather made of cattle hides with covering	0.60	16.90	9.40	126.40	0.37	0.10
Artificial lining leather						
Vinyl HT	0.80	2.30	2.10	10.00	0.04	0.05

In this study, hygienic properties of shoe materials having various origin and application were evaluated: natural lining and insole leathers made of pigs, horses and cattle hides, skins, and artificial leather based on Vinyl HT fabric, the latter designed for men shoe lining (see Table 1).

Hygienic properties of these materials were determined by standard methods of testing of shoe materials [8, 9].

Results and discussion

Based on the analysis of obtained data natural undyed lining pig leather with higher indices of wetting, capillarity and water vapour permeability was selected as a reference material. In order to assess comfort level of studied shoe materials, a graphically-numerical method was used. According to which the comprehensive assessment of important hygienic properties of investigated material corresponds to the area of pentagon formed on the basis of the scaled indices K_i of these properties ($K_i = P_i : P_s$, where P_i, P_s – indices of hygienic properties of investigated material and standard material), and the ratio between pentagon area of this material S_i and pentagon area of standard material S_s corresponds to the level of comfort for the sample ($LC_i = (S_i : S_s) * 100$) (Table 2).

Table 2. Comprehensive assessment of hygienic properties and level of comfort of shoe materials

Index		Lining leather							
		Undyed		Dyed without covering		Dyed without covering		Dyed with covering	
		made of pigskin				made of cattle hides			
name	base Ps	P_i	K_i	P_i	K_i	P_i	K_i	P_i	K_i
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Hygroscopicity, %	13.60	13.60	1.00	8.70	0.63	9.00	0.66	6.40	0.29
Moisture return, %	10.70	10.70	1.00	6.50	0.60	7.65	0.71	5.16	0.05
Wetting, %	149.20	149.20	1.00	87.07	0.58	84.90	0.57	98.96	0.66
Capillarity, cm^2/ min	3.14	3.14	1.00	0.39	0.12	0.07	0.02	0.35	0.60
Water vapour permeability, $mg/cm^2 \cdot hour$	0.33	0.33	1.00	0.21	0.63	0.16	0.50	0.19	0.57
Comprehensive assessment S	–	23.00		6.21		4.39		5.52	
Level of comfort LC, %	–	100.0		27.0		19.1		24.0	

Continuation of table 2

Lining leather		Split for lining		Insole leather						Vinyl HT for lining	
Dyed with covering				Dyed without covering		Dyed with covering					
made of horse		made of pigskin		from cattle hides							
P_i	K_i	P_i	K_i	P_i	K_i	P_i	K_i	P_i	K_i	P_i	K_i
11	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*
30.08	2.20	2.90	0.21	5.01	0.37	4.30	0.31	16.90	1.25	2.30	0.17
16.08	1.50	2.00	0.18	6.30	0.59	4.66	0.43	9.40	0.87	2.10	0.19
82.23	0.55	88.40	0.59	40.05	0.27	60.90	0.04	126.40	0.85	10.00	0.07
0.07	0.02	0.27	0.08	0.10	0.03	0.03	0.01	0.37	0.12	0.04	0.01
0.12	0.36	0.18	0.54	0.90	2.70	0.10	0.28	0.10	0.30	0.33	0.15
22.68		1.86		6.67		1.10		10.76		0.32	
98.6		8.1		29.0		4.8		46.8		1.4	

Thus, it was found the following ratio between pentagon areas depicting investigated leathers and the same for reference leather sample is as follows: dyed lining leather without covering made of pigskin – 27.0 %; dyed lining leather without covering made of cattle hide – 19.1 %; dyed lining leather with covering made of cattle hide – 24.0 %; dyed lining leather with covering made of horse skin – 98.6 %; lining split made of pigskin – 8.1 %; dyed insole leather without covering made of cattle hides – 29.0 %; dyed insole leather with covering made of cattle hides (thickness 2.5 mm) – 4.8 %; dyed insole leather with covering made of cattle hides (thickness 0.6 mm) – 46.8 %; artificial lining leather Vinyl HT – 1.4 % (Table 2, Fig. 1).

By comparing the data obtained, we may conclude that hygienic properties (comfort) of shoe materials largely depend on the method of treatment, which determines their structure and properties. This does not contradict the known [10-12] and own data. Thus, depending on the stage of polymer dispensing, polymer type and size of particles, the hygienic properties of chrome leather for shoe upper leather without covering made of raw cattle hides are changing (Table 3).

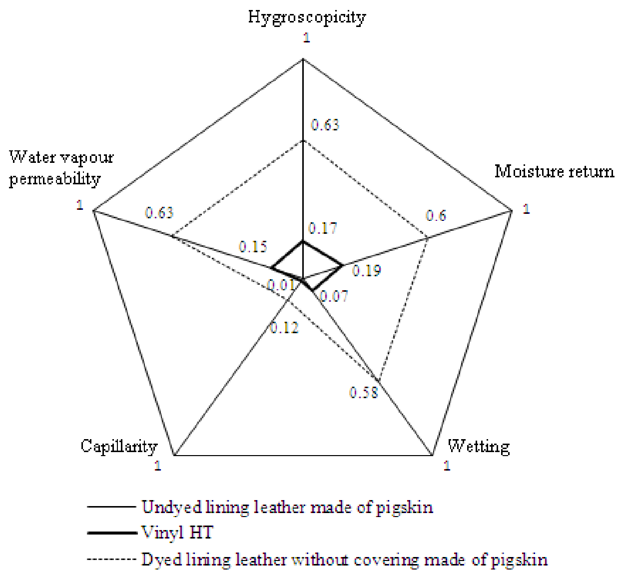

Figure 1. Comprehensive assessment of hygienic properties of lining materials

Table 3. Influence of dyeing conditions in the presence of polymer on hygienic indices of leather for upper of shoe

Polymer	Particle size, nm	Porosity, %	Water vapor permeability, mg/cm^2·hour
Polymaleate	17	54.3/53.1	3.3/2.9
Polyacrylate №1	78	54.4/56.0	3.1/3.3
Polyacrylate №2	562	53.2/54.8	2.8/3.1

Note: numerator – the introduction of the polymer before, the denominator – after dyeing

In our case, the treatment of leather by dyes and fats, as well as covering them (Table 1, 2), aggravated some of the hygienic properties of shoe materials. In particular, dyeing of lining leather made of pigskin reduced its capillarity, which caused further negative effect to the value of pentagon area.

The best hygienic properties of lining leather types were observed for leather made of raw horse skin (thickness 0.6 mm): the percentage ratio between the relevant pentagon area and the pentagon area of the reference leather is 98.6 %.

As for insole leathers, the best results correspond to the leather produced from raw cattle hides (comprehensive assessment value is 46.8 %).

For artificial leather (Vinyl HT), designed for men's shoe lining, the pentagon area observed was considerably smaller compared with reference leather: its level of comfort is 1.4 % (Fig. 1). Thus, based on the obtained results it is arguable that the inside casual shoes details made of Vinyl HT are unable to provide for appropriate comfort conditions. Therefore, the use of artificial material for making closed casual shoes lining (in boots, shoes, etc.) is unacceptable.

Conclusions

Quality indicators of shoes as light industry commercial products were systematized according to European standards, focused to meet the needs of the person. It was determined that, in order to ensure competitiveness, the ergonomic characteristics (anthropometric, hygienic and psycho-physiological) must be taken among the main criteria in evaluating consumer properties of footwear. Here, the hygienic properties play critical role, as it is they that facilitate psychological feel-good experienced by a person in «consumer-shoes-environment» system.

Based on Rehbinder Theory the following assumptions were made for the type of secreted moisture binding with the material of inside space of a shoe when wearing (for example, everyday low shoes) in closed rooms: in comfortable conditions moisture remains in physic-chemical bond with inside materials (lining and insole) of shoes; in discomfort environment created by intense sweating (humidity increases up to 75 %), moisture forms physical-chemical bond with shoe materials with excessive moisture content, affecting hygienic properties of shoes and consumer's sensations. It is shown that, according to consumer's subjective feelings (psychological comfort or discomfort in wearing shoes) conditioned by objective ambient factors such as environmental conditions (temperature, humidity, etc.), the hygienic properties of shoes and materials the shoes made of, play a special role. In particular, hygroscopicity, moisture return, wetting, capillarity and water vapour permeability are the main parameters that reflect the ability of materials to absorb and localize products of sweating. It is important, especially when, in long-term wearing of shoes a higher humidity (W=75 %) is observed. It is caused by an intensive sweating of foot.

With the use of obtained results, a new graphically-numerical method was tested in assessment of shoe material comfortability, the materials that have direct contact with the human foot. According to the method, the ratio between pentagon areas of material tested and reference material is taken as quantitative indicator of quality. The best hygienic properties among lining leathers were awarded to horse leather (level of comfort – 98.6 %), among insole leathers – to the leather made from cattle hides (level of comfort – 46.8 %). The worst material for casual shoes lining is artificial leather Vinyl HT, with the ratio between pentagon area of the latter and pentagon area of reference standard material showing only 1.4 %. That is, the inside details of shoe upper made of Vinyl HT artificial leather do not provide appropriate conditions of comfort during prolonged exploitation.

The results of work show benefits of new graphically-numerical method in comprehensive assessment of shoe material hygienic properties. The «pentagon» method provides for sufficiently complete as well as accurate information about the hygienic properties of shoe materials that stay in direct contact with human foot, and can be used for hygienic examination of shoe material quality and in selecting (confection) the set of materials in production of certain type of shoes.

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