DIVERGENCE OF UPPER MATERIALS TO SPECIFIC FOOTWEAR CONSTRUCTION: SEEKING A CULTURE OF SUSTAINABLE MATERIAL SOLICITATION

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Footwear is equally a fashion and function apparel item constructed of leather and non-leather materials. This research aims to investigate the selection of materials for footwear fabrication corresponding to shoe functionality and fashion aspects of consumers. Here, an attempt is taken to build a network among the consumer perception of cherry-picking shoes, sustainable fashion, and the physicomechanical behavior of versatile upper materials focusing on leather and non-leather. A psychometric rating scale is used to rate the relationship of sustainability attitude regarding both materials and users. The chosen materials are leather, pleather, and fabric. The leather items are suede, semi-aniline, and corrected grain leather whereas non-leather materials are canvas cotton, PUCF, and PVCF. The randomly selected materials with a thickness of 1.2-2.4 mm for the dress (oxford), casual, and boot shoe fabrication were brought under rigorous physicomechanical tests following ISO and SATRA methods. Besides, a quantitative statistical analysis of psychophysical material information test was carried out among 132 valid respondents. Though cent-percent of finished leather and most of the canvas fabric samples have satisfied standards of physicomechanical characteristics whereas pleather was underneath. The weighted score for green materials solicitation for sustainable use was 2.5 ± 0.01on a psychometric rating scale of 5.00, quite unsatisfactory due to a deficiency of materials knowledge among consumers. Moreover, the Pearson correlation coefficient is about 0.99152 and a p-value of $0.03 \angle 0.05$ has been observed which provided strong evidence of a statistically significant positive correlation among the variables on the sustainability attitude scale of material cherry-picking.

Keywords: Footwear, upper materials, sustainability.

INTRODUCTION

Footwear is a wearing attire that has been designed for the feet to protect, adorn and comfort. In addition, most recently footwear has become a significant part of fashion associates, performance items, and even considered an energy harvester (Ujević *et al*., 2009; Soloman, 2021; Goonetilleke and Weerasinghe, 2011). The footwear generally consists of two principal parts recognized as upper and bottom. The footwear industry uses diverse types and styles of shoe materials such as leather, synthetic materials, poromerics, rubber, leatherette, naugahyde, vegan or faux leather, multiple textiles, composites, foamposities, etc., materials are among the rudimentary materials most frequently used in footwear assembly. Each material has its specific characteristics. Design and material assortment measures meaningfully affect not only the shoe's lifecycle but also its end-of-life supervision (Ujević *et al*., 2009; Staikos and Rahimifard, 2007; Meyer *et al*., 2021). The usage of the terms artificial leather, synthetic leather, leatherette, imitation leather, faux leather, man-made leather, bonded leather, pleather, textile leather, or polyurethane (PU)-leather is restricted in Europe by the European standard EN 15987 (Meyer *et al*., 2021). From the viewpoint of a global perspective, footwear worldwide production has reached 24.3 billion pairs in 2021 with an economy of $105.8 billion. The manufacturing sites are deeply focused on the territory of Asia. Bangladesh shares more than 1.6% of the world's total footwear consumption and secured its position in the world's top ten shoe consumption matrix -2021 (World Footwear Yearbook 2021). According to the Export Promotion Bureau, leather and leather products is the second-largest sector of Bangladesh in terms of exports, after ready-made garments, exported leather and leather products were worth $1.2 billion in the FY

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2020-2021. Which is about 2.43 percent of the total export earnings of the country ($38.758 billion). In Bangladesh, there are 42 automated and over 4500 non-automated large and cottage-level footwear production units that continuously satisfy the national and international demand for various kinds of footwear (Hasan *et al*., 2016). Despite its stretched expansion and contribution to Bangladesh's economy, research on footwear materials has not been broadly undertaken.

This study inspected the dynamics of the sustainable upper materials consumption practice, selection culture, and approach in certain categories of footwear apparel production in Bangladesh. Here, a comparative analysis of physicomechanical properties of shoe upper leather and alternative materials (pleather and canvas fabric) was done to give a guide to the footwear manufacturers both local and exporters regarding the solicitation of quality materials for footwear production and sustainable development of the sector. Moreover, a psychometric test on consumers' behavioral intention to use leather-made foot apparel through a structured questionnaire was conducted to elucidate the cultural facts about non-leather footwear use.

MATERIALS AND METHODS

Materials

There were eighteen different types of footwear upper materials samples among which nine were chrome tanned leather, three of each PVCF (Polyvinyl Chloride-Coated Fabric) and PUCF (Polyurethane Coated Fabric), and three canvas textiles were collected randomly from prominent export-oriented footwear industries around Dhaka city. The SATRA- thickness gauge tester (0.01mm least count) was used to measure the thicknesses of test samples. The details of the test specimens are provided in Table 1.

Methods

In any experimental research, sampling, conditioning, and machine calibration are the prime importance to meet results accuracy. Prior to testing, all the samples were conditioned in a standard atmospheric of 48 hours, 27±2°C, and 65±2% of RH (Relative Humidity). Sharp press knives with 18 mm deep and 200 cutting edge angle (ISO 2419) were used for cutting the specimen (Dutta, 1990; Bayes *et al*., 2013). Triplicate tests of different physical and mechanical experiments were carried out in the laboratory to assess the quality of shoe upper materials (leather and non-leather) and minimize errors. The carried out tests, equipment, method of analysis, etc., are shown in Table 2.

Statistical Analysis

A survey was conducted among 132 valid subjects (73 men, age - 27 year, and 59 women, age - year) to perform statistical analysis. The observation was based on a structured questionnaire. The order of questions is focused on a sustainability attitude scale modeling shown in Fig. 1. And administered to comprehend the perception of subjects' (consumer) decision approach to buying and using leather and non-leather made footwear in their daily life, and knowledge of footwear quality linked with material sustainability. A psychometric scale (Likert scale) was used to evaluate the skepticism of consumers' dissuasive attitude toward the application of material sustainability knowledge and culture in purchasing footwear. The numerical ratings of 5 – 1 were allotted to the feasible Likert answers of intensely approve – intensely disapprove in order to reach a minimum mean value. The weighted score (WS) was computed using Eq. (1).

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Table 1. Sample specification

ID No.	Shoe Style	Upper Category	Color	Thickness (mm)	Yarn Count Warp	Weft
S1	Casual	Cow, corrected grain	Black	1.22		
S2		Cow, corrected grain	Black	1.23		
S3		Cow, corrected grain	Black	1.28		
S4	Boot	Cow, Suede	Brown	1.92		
S5		Cow, suede	Brown	2.11		
S6		Cow, suede	Brown	2.38		
S7	Dress	Cow, semi-aniline	Red	1.31		
S8		Cow, semi-aniline	Red	1.32		
S9		Cow, semi-aniline	Red	1.33		
S10		PUCF (woven backer)	Grey	1.21	45	45
S11	Dress	PUCF (woven backer)	Grey	1.24	45	45
S12		PUCF (woven backer)	Grey	1.31	45	45
S13	Casual	Canvas (cotton)	Blue	1.23	75	110
S14		Canvas (cotton)	Black	1.22	75	110
S15		Canvas (cotton)	Blue	1.25	75	110
S16	Boot	PVCF (non-woven baker)	Pink	1.91		
S17		PVCF (non-woven baker)	Pink	1.89		
S18		PVCF (non-woven baker)	Pink	2.21		

$$WS = \sum_{1}^{n} \frac{nx}{N} \qquad (1)$$

where, x = number of responses; n = rating score of question; and N = total number of valid subjects. The Pearson correlation test was also conducted with the hypothesis maintaining a 95% confidence interval with df. = n-1. The null hypothesis is no correlation between the parameters of materials sustainability and the specific shoe construction and vice versa is the alternative hypothesis has been considered.

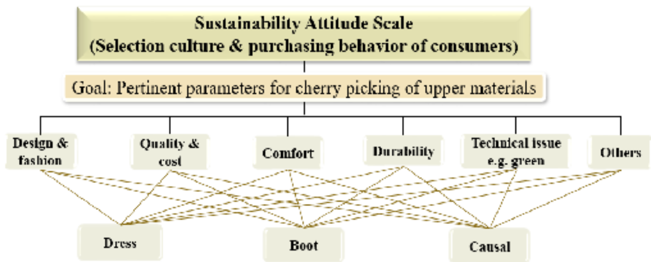

Figure 1. Material selection model for specific footwear construction

Table 2. Tests, analysis method, and equipment

Experiments	Method of analysis	Equipment
Thickness of upper materials	ISO 2589 (Leather); ISO 9073-2(Textile)	Thickness gauge, SATRA STD 483 (Leather), STD 484 (synthetic & other materials)
Sampling location and preparation (Leather)	ISO 2418-9	-
Sample conditioning	ISO 2419/ ISO 554	
Tensile Strength (TS) & Elongation (E)	ISO 3376	Tensile tester, STD 172
Stitch Tear (double hole) strength (ST)	ISO 3377/ SATRA- PM 5	Tensile tester, STD 172
Tongue Tear strength (TT)	ISO 3377	Tensile tester, STD 172
Finish film Adhesion (FA)	SATRA-TM 408	Adhesion of Finish tester, STD 112

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Experiments	Method of analysis	Equipment
Water Vapor Permeability (WVP)	ISO 14268/ SATR- PM 172	Water Vapor permeability machine STM 473
Grain Crack Index (GCI); Load (L) & Distension (D)	ISO 3378-9/ SATRA- STM 104	Digital Lastometer, STM-463
Flex Resistance (FR)	ISO 5402/ SATRA-TM 147	Flexing machine, STM 141
Yarn count Ne (textile)	ISO 7211-5	-
Rub Fastness (RF) (wet & dry)	ISO 11642/ SATRA-TM 08 ISO 105-X10 (PU & PVC)	Rub Fastness tester, STM 462/ (coloring ISO 105-A02 & Staining ISO 105-A03)
Fastness to Water spot (FW).	ISO 15700	-

RESULTS AND DISCUSSION

The physicomechanical test results have been provided in Table 3. Among all the experiments, the most significant mechanical properties for shoe upper materials selection are Tensile Strength (TS) and Stitch Tear (ST) strength (ISO 3377-1:2011; ISO 3376:2020). The results for both parameters vary a little among the corrected grain, suede, and semi-aniline leather whereas in the case of pleather (PUCF & PVCF) wide-ranging range of gaps are observed from the shoe upper standard values and even from naturally grown sample leather used in this research work.

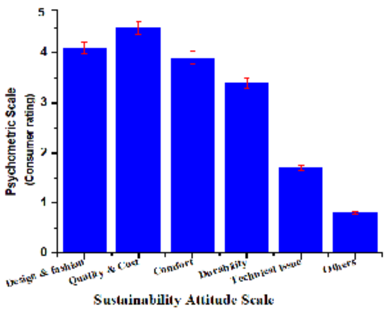

Figure 2. Sustainability scale rating

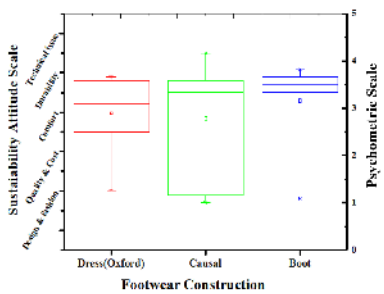

Figure 3. Consumer perceptions of specific footwear

The three categories of upper leather for the dress (Oxford), boot, and casual have shown a very high mechanical stability (TS, ST, WVP, and GCI), demonstrating the utmost values which scenario is crystal clear in the data table. TS, ST, and, WVP values have exceeded the specification of > 15 N/mm^2 (ISO 3376), min 78 N/mm (ISO 3377), and min 0.8 (ISO 14268), and, > 35 N (ISO 3378-9) respectively for chrome-tanned shoe-upper leather (ISO 3377-1:2011). The percentage of elongation (% E), TT, FR, RF (wet & dry), FW, etc., are also in minimum requirements. On the other hand, pleather did not achieve any of the technical requirements properties under the yardstick of ISO or SATRA recommendation. This diminutive performance of % E highlighted that the Pleather has poor elasticity, TS, ST, and, WVP to adjust to the user's feet and the actions (forward torque 14.2 N.m) consequent from the wearer of footwear. The normal range of pressures on the foot surface is about 150–400 KPa during a simple way of walking at the dorsal foot dorsum (Ruperez *et al*., 2009; Rupérez, 2012).

Moreover, during the footwear fabrication, the resultant 3600 force provided on the upper materials by pincers of toe lasting machine easily tears the surface of pleather due to making processes.

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Table 3. Physicomechanical tests result of upper materials

Upper material types	Shoe Type	Thickness, mm Mean ± SD	TS, N/mm² Mean ± SD	E, % Mean ± SD	ST, N/mm Mean ± SD	TT, N/mm Mean ± SD	WVP, mg/cm².h Mean ±SD	FA, N/m Mean	GCI/ L (N); D(mm) Mean L	D	FR, (25000, Cycle), Break pipiness rating	RF, wet (128) & dry (1024)	S, mm Mean ±SD
Corrected grain	Casual	1.24 ± 0.03	19.18 ± 0.65	47 ± 2.0	81.5 ± 0.5 3	36.71 ± 1.0 8	0.8 ± 0.04	0.5	35.5 4	7.4 5	2	4/5	4.35 ± 0.16
Suede	Boot	2.14 ± 0.23	22.44 ± 1.10	67 ± 11.0	86.07 ± 3. 88	40.88 ± 1.6 3	0.9 ± 0.06	-	38.2 7	7.1 2	3	4	3.97 ± 0.28
Semi-aniline	Dress	1.32 ± 0.01	18.46 ± 0.50	45 ± 3.0	78.29 ± 1. 61	31.86 ± 0.4 8	0.9 ± 0.02	0.4	36.2 3	7.3 2	3	4/5	2.79 ± 0.32
PUCF	Dress	1.25 ± 0.05	10.03 ± 0.51	27 ± 3.0	52.67 ± 0. 68	14.36 ± 0.8 0	0.55 ± 0.06	0.2	18.5 6	5.9 5	6	2/3	1.97 ± 0.15
PVCF	Boot	2.01 ± 0.18	10.87 ± 1.97	22 ± 1.0	28.55 ± 1. 74	16.48 ± 0.9 7	0.38 ± 0.06	0.1	17.2 5	6.8 9	6	2/3	3.97 ± 0.22
Canvas	Casual	1.23 ± 0.02	17.07 ± 0.41	31 ± 2.0	78.92 ± 0. 26	27.35 ± 1.0 1	1.85 ± 0.02	-	29.4 0	7.2 5	-	-	2.69 ± 0.11

The psychometric scale (Likert rating) has represented in Fig. 2. where the results revealed that technical issues (e.g., green material) were less addressed by the consumer

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on purchasing shoes. The perception of men and women are presented in an aggregated way in the bar diagram. The rating of products quality and cost has the topmost score of 4.5 ± 0.23 that's signified quality improvement and price down must be the challenging issue in case of material solicitation. Moreover, comfort has been rated undisputed parameter. It is clear from the box plot in Fig. 3 that a positive correlation existed between the choice of categories of footwear and the sustainability scale e.g., quality and cost, and durability.

Most of the data are concentrated on the 50% region in the case of dress (median 3.1) and boot (median 3.5) shoes. In addition, the Pearson coefficient for dress (Oxford), boot and casual footwear has been calculated and were 0.99152 (p-value 0.03644); 0.92188 (p-value 0.00891), 0.83979 (p-value 0.0166) respectively. So, the p-value was less than 0.05 ($p \leq 0.05$) observed is an indication of a strong relationship exists between the scale of sustainability and the consumer choice of different footwear styles during purchase and usage and the null hypothesis has been rejected.

CONCLUSION

The inquiry of sustainable properties of leather material with alternatives has been crystal clear to the manufacturer and the answer has been inherent with natural leather's internal geometric structure. The physicomechanical properties of leather are the ultimate proof of the most unique material indeed. The breathability property is the prime importance for footwear production which was measured by water vapor permeability. This property is absent in pleather. The psychometric test also signified that consumer perception of buying and using footwear is based on comfort, quality, durability, and cost. The manufacturer should have to consider materials physiognomy along with consumer perception to sustain a culture of selecting suitable materials for specific footwear to fulfill the aspiration of the sustainability of the sector.

REFERENCES

Bayes, T.J.W. *et al*. (2013), *Basic Shoemaking: A Step by Step Guide to Shoemaking*, SATRA Technology Centre Limited, Northamptonshire, ISBN 978-0-907924-20-3.

Dutta, S.S. (1990), *An Introduction to the Principle of Physical Testing of Leather*, Indian Leather Technologists' Association, Kolkata, ISBN 81-901423-0-5.

Goonetilleke, R.S. and Weerasinghe, T.W. (2011), "Getting to the Bottom of Footwear Customization", *Journal of Systems Science and Systems Engineering*, 20(3), 310-322, https://doi.org/10.1007/s11518-011-5171-0.

Hasan, M.N., Paul, T., Hasan, M.N. and Hashem, M.A. (2016), "Estimation of VOCs Emission from Different Adhesives Used in Shoe Manufacturing", *International Conference on Mechanical, Industrial and Energy Engineering*, 4, 1-4, https://www.researchgate.net/publication/354528841.

Rupérez M.J., Giner, C.E. and Monserrat, E. (2012), "Simulation of the Behavior of the Calfskin Used as Shoe Upper Material in Footwear CAD", *Computer-Aided Design*, 44(12), 1205-1216, https://doi.org/10.1016/j.cad.2012.06.009.

Ruperez, M.J., Monserrat, C. and Alcañíz, M. (2009), "A Study of the Viability of Obtaining a Generic Animation of the Foot while Walking for the Virtual Testing of Footwear Using Dorsal Pressure", *Journal of Biomechanics*, 42(13), 2040-2046, https://doi.org/10.1016/j.jbiomech.2009.06.054.

Soloman, B.B. (2021), "Leather Cutting Waste Minimization Techniques in Ethiopian Footwear Industry: Case Study ELICO - Universal Leather Products Industry", Research Square, Bahir Dar University, https://doi.org/10.21203/rs.3.rs-274284/v1.

Staikos, T. and Rahimifard, S. (2007), "A Decision-making Model for Waste Management in the Footwear Industry", *International Journal of Production Research*, 45(18-19), 4403-4422, https://doi.org/10.1080/00207540701450187.

Ujević, D., Kovačević, S., Wadsworth, L.C., Schwarz, I., and Šajatović, B.B. (2009), "Analysis of Artificial Leather with Textile Fabric on the Backside", *Journal of Textile and Apparel Technology and Management*, 6(2), 1-9, https://www.researchgate.net/publication/277112454.

*** (2011), ISO 3377-1:2011 Leather-Physical and Mechanical Tests-Determination of Tear Load—Part 1: Single Edge Tear, ISO: Geneva, Switzerland.

*** (2021), *World Footwear Yearbook* (https://www.worldfootwear.com/).

https://doi.org/10.24264/icams-2022.V.1