Comfort, Chemical, Mechanical, and Structural Properties of Natural and Synthetic Leathers Used for Apparel

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ABSTRACT: Natural leather is processed from hides and skins of animals. Synthetic leathers are becoming popular as an alternative material owing to limited availability and varying size of natural leathers. There is a need to understand the properties of natural and synthetic leathers to select proper material for an application. In this study, materials used for apparel application such as natural sheep nappa leather and synthetic polyurethane (PU)-based leather have been chosen and analyzed for comfort, chemical, physical, and structural properties. It was found that natural sheep nappa leather has enhanced water vapor permeability whereas other comfort properties such as softness and drape ability are comparable to synthetic PU leather. Whereas synthetic PU leather dominated most of the physical properties, especially percentage elongation and stitch tear strength, in specific directions on account of polyester knitted base fabric. Chemical properties of natural sheep nappa leather and synthetic PU leather depended on the individual material composition and characteristics. Scanning electron microscopic (SEM) analysis provided convincing evidence for some of the quantified comfort and physical properties. The results of this study would be useful in selection of proper material for apparel application as well as in providing directions for future research in synthetic leather manufacture. © 2009 Wiley Periodicals, Inc. J Appl Polym Sci 114: 1761–1767, 2009

Key words: drape; porosity; fibre; strength; garment; structure; electron microscopy

INTRODUCTION

Leather manufacturing helps in the utilization of coproduct of the meat industry namely, hides and skins.[1] Leather, the unique biofabric, is obtained by tanning of the raw hides and skins resulting in long life due to the prevention of degradation even if it is kept wet. The most important leather forming constituent of the skin is collagen, the protective substance of the white fibers of connective tissue.[2] A close examination of the makeup of a piece of skin shows that it consists primarily of long thick fibers and fiber bundles interweaving in three dimensions. This gives the skin-based materials many of their unique physical qualities.[3] Processing of leather is generally classified in three groups viz., pretanning or beam house processes, tanning and post-tanning, and finishing.[4] Pretanning processes aim at cleaning and preparing of hides/skins for tanning, tanning stabilizes the hide/skin matrix permanently[5] against microbes and heat and esthetic values are added during post-tanning and finishing. Garment leathers are produced either as nappa or suede. Nappa leathers with good drape are easily produced from sheep skins and they have resin finished grain surface.[6] In the sheep skin, the collagen is extremely thin and not closely interwoven. They tend to run parallel to the skin surface, which makes soft, pliable, and loose texture.[2]

The insufficient supplies and high cost of genuine leather brought about the demand for synthetic leather that possesses the essential qualities of leather, which are uniform substance, shade, stretch, softness, etc. Some properties of synthetic leather are even better than those of natural leathers, such as softness, crease resistance, strength, elongation, easy-care, easy volume production, and so on.[7] Over the past few decades, the demand for high quality synthetic leather has increased tremendously.[8] The known commercial synthetic or artificial leathers ordinarily consist of a textile base layer, especially a compressed fibrous web or fleece, which has been impregnated with an elastomeric bonding agent, and a microporous cover or top layer firmly adhered to this base layer. Polyurethane (PU) is most commonly used both as a bonding agent and also for the formation of top layer. Textile base layer is mostly made up of woven or nonwoven or knitted fabric backing in which the fiber direction depends on the

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particular manufacturing process. Conventional synthetic leather manufacture involves application of polymers either in lacquer or emulsion form onto a fabric. There are two different methods of application namely direct and transfer coating. In the direct method, viscous polymer solution or emulsion is spread directly onto the fabric using conventional spreading plant and dried. Transfer coating technique involves two-stage process of first applying the polymer onto a release paper to form a film. Then it is allowed to dry partially and transferring and bonding it to the fabric surfaces. Nonetheless, poromeric imitation leathers are a group of synthetic 'breathable' leather substitutes made from a plastic coating (usually a PU) on a fibrous base layer.[8] Aesthetically the softness and suppleness of PU coatings result in good drape for clothing's properties, which can be enhanced by the selection of flexible base fabrics such as warp knitted nylon or circular knitted polyester.[9]

A detailed search in the literature on the comparison of properties between synthetic and natural leather reveals a dearth of information on the same.[10] Hence, an attempt has been made to obtain a better understanding of natural and synthetic leather used for apparels. Studies have been carried out to analyze the mechanical, comfort, and chemical properties of natural and synthetic leather and correlate them with their structural characteristics so as to understand and select proper material for a particular application for better performance and durability.

EXPERIMENTAL

Materials

Natural sheep nappa leathers meant for garment application were procured from a commercial tannery in Chennai. Synthetic PU leathers meant for garment application were procured from DCP Synthetics, Chennai. The description of the procured synthetic PU leathers is shown in Table I.

Sampling and conditioning

Samples from both natural and synthetic leathers were obtained from official sampling position and conditioned at 20 ± 2°C with a relative humidity of 65 ± 4% for 48 h before all comfort, physical, and chemical testing.[11] For all the tests, four samples were taken from both natural and synthetic leathers and the average values were calculated along with standard deviation using statistical analysis and reported. For certain tests, such as tensile strength, stitch tear strength, and percentage elongation at break, samples were taken from parallel and perpendicular directions of the backbone of natural leathers and the average values were obtained by statistical analysis. Although synthetic leathers do not have any backbone, the polyester knitted base fabric of PU leather has course and wale directions. The row of loops in the longitudinal direction of the fabric is called wale (vertical rows), whereas the row of knit loops in the width direction is named as course (crosswise rows). In this study, samples were taken from course direction and termed as perpendicular whereas samples from wale direction were termed as parallel for ease of comparison with natural leather samples. The average values of these were obtained by statistical analysis.

TABLE I
Description of the Synthetic PU Leathers Meant for Apparels

PU leather thickness	0.74 mm
PU leather density	104 g/m^2
Fabric type	Polyester knitted
Fiber type	Polyester
Yarn count	30 Ne
Knit type	Loop knit (or) French terry
Wales & Course/cm	22/16

Measurement of comfort properties

Softness of the leather specimens was measured using a MSA ST300 digital leather softness tester supplied by M/s MSA Engineering Systems Limited, UK following standard procedure.[12] The method permits measurement of softness using a 25 mm ring. Measurements were carried out on five locations within the sampling area and reported as an average. Higher values indicate higher softness. Drape is the extent to which a fabric will deform when it is allowed to hang on an object under its own weight. This was measured by calculating the drape coefficient as the ratio of the projected area of the drape specimen to its theoretical maximum. The conditioned leather samples were tested using drape tester following standard procedure.[13] The water vapor permeability is the amount (mg) of water vapor passing through unit area (cm^2) of the leather specimen in a unit time (h). The leather samples were tested following standard procedure.[11]

Analysis of chemical properties

The pH of distilled water extract of leather was analyzed following standard procedure.[11] The specimen was weighed and transferred to Erlenmeyer flask. Water in the amount of 20 times the mass of the specimen was added to the flask, stoppered, and agitated thoroughly at the standard laboratory temperature for 5 h. The pH of the extract solution was

TABLE II
Comfort Properties of Natural Sheep Nappa and Synthetic PU Leathers

Leather samples	Softness (mm)	Drape coefficient (%)	Water vapor permeability (mg/cm^2)
Sheep nappa	6.0 ± 0.3	47.5 ± 1.1	5.3 ± 0.2
PU	5.7 ± 0.2	45.2 ± 2.0	1.8 ± 0.4

read using a digital pH meter. Total ash content of natural and synthetic leathers was estimated following standard procedure.[11] A known sample of 1–5 g of leather was transferred to the crucible and was initially burnt-off carefully over a gas burner to remove oil. Then it was placed in a muffle furnace at 600 ± 25°C for at least 15 min. Then it was removed from muffle furnace, cooled in a desiccator, and weighed. The operation was repeated until a mass constant within 0.2 mg was obtained. The ash content was calculated as a percentage using the weights of ash and original sample. The moisture content of natural and synthetic leathers was analyzed following standard procedure.[11] Cut samples of each 5 ± 1 g were transferred to a dry weighing bottle, capped, and weighed. The bottle containing the sample was heated in a mechanical-convection oven at 100 ± 2°C for 16 ± ½ h. Then it was cooled in a desiccator for 2 h and weighed. The moisture content was calculated as a percentage using the weights of moisture and original sample. Shrinkage temperature is the temperature at which the leather samples shrinks when heated in an aqueous medium. This was measured following standard procedure using a shrinkage meter apparatus.[11]

Analysis of mechanical properties

Bending length equals half the length of rectangular strip of fabric that will bend under its own weight to an angle of 41.5°. This was measured following standard procedure.[14] Tensile strength is the load (N) per unit area of cross section (mm^2) required to rupture or break a strip of leather. The conditioned leather samples were tested using universal testing machine (M/s Instron Inc., UK) following standard procedure.[11] The extent of elongation of the leather specimen at the time of breaking, while applying the tensile force, was measured as the percentage on the original length of the said specimen. The elongation was measured simultaneously during the measurement of tensile strength and expressed as a percentage. The conditioned leather samples were tested using the same machine for measuring the double hole stitch tear strength following standard procedure.[11]

Scanning electron microscopic analysis

Samples from natural and synthetic leathers were cut from the official sampling position.[11] Samples were cut into specimens with uniform thickness. A Quanta 200 series SEM was used for the analysis. The micrographs for the grain surface and cross section were obtained by operating the SEM at low vacuum with an accelerating voltage of 12 kV in different lower and higher magnification levels.

RESULTS AND DISCUSSION

Comfort properties

The comfort properties of natural and synthetic leathers meant for apparels have been evaluated and shown in Table II. Results suggest that the natural leathers used for apparels (sheep nappa) have high water vapor permeability and comparable softness and drape coefficient values in relation to PU leathers. Natural leather used for apparels has a drape coefficient of 47.5 ± 1.1 and PU leather has a drape coefficient of 45.2 ± 2.0, as shown in Table II. Lower values indicate better drape ability. The drape coefficient value of natural sheep nappa leather is in agreement with that was reported earlier.[15] Although natural leathers meant for apparels application are available from various animal sources, higher softness and drape coefficient of sheep nappa leather demonstrates its suitability for apparel application. Sheep nappa leather possesses higher water vapor permeability when compared with PU leather. The increased water vapor permeability may be due to the intrinsic pore connectivity as well as hydrophilicity associated with the natural leathers.[3,16] It is known that the natural leathers have nano-, micro-, and macropores in the range of 0.3 nm to 150 μm.[17–19] Besides natural leathers contain numerous positive and negatively charged side chain amino acid groups apart from the charges present in the chemicals used for leather processing such as tanning agent, syntans, fatliquors, and dyes.[3] Hence, the hydrophilic nature of natural leather is also an important factor for attracting dipolar water molecules. Conversely, synthetic PU leathers contain hydrophobic polymers such as PU and polyester in the top and bottom layers, respectively, which inhibits the attraction of water molecules toward them.

Chemical properties

The chemical properties of natural and synthetic leathers were analyzed and given in Table III.

TABLE III
Chemical Properties of Natural Sheep Nappa and Synthetic PU Leathers

Leather samples	pH	Ash content (%)	Moisture content (%)	Shrinkage temperature (°C)
Sheep nappa	3.71 ± 0.2	6.2 ± 0.4	11.3 ± 0.2	110 ± 1.0
PU	7.62 ± 0.1	21.8 ± 0.1	0.6 ± 0.7	118 ± 2.0

Results suggest that the natural leathers used for apparels (sheep nappa) possess low pH value of 3.71 ± 0.2 when compared to synthetic leathers. However, this is in agreement with the standard requirement for natural leathers meant for various applications.[20] On the other hand, synthetic leathers meant for apparels (PU) have pH value of 7.62 ± 0.1, as shown in Table III. The natural leathers have low ash content compared to synthetic leathers. Natural sheep nappa leather has high moisture content when compared to that of PU leather. Higher moisture content in the natural leathers is owing to the fact that water is an integral part of the architecture of skin. Five levels of hydration is reported in the skin matrix. Of which, the bound water is known to present even if the leather is dried under high temperature in the range of 100°C.[21] Synthetic leathers have higher shrinkage temperature values compared to natural leather. Shrinkage temperature values associated with the natural leather depend on the extent and kind of tanning process. Higher shrinkage values for the synthetic leather may be due to the choice of polymer and the reinforcement given to the skin surface layer. It should be noted that the shrinkage temperature values do not mean the glass transition temperature; it signifies the hydrothermal stability of the matrix.

Mechanical properties

The mechanical properties of natural and synthetic leathers were analyzed and presented in Table IV. Lower bending length value suggests better bending indicating better drape ability and less stiffness of samples. PU leather possesses marginally low bending length values in both the direction when compared to sheep nappa leather. Although tensile strength is not an important property for apparels, it was examined in this study to compare the tensile properties between two different materials. The synthetic leathers used for apparels (PU) have high tensile strength in parallel direction when compared to that of sheep nappa leather. However, in the perpendicular direction, sheep nappa leathers have high tensile strength when compared to PU leathers. The percentage elongation at break is similar in both the directions of natural sheep nappa leather. In parallel direction, sheep nappa leather has high percentage elongation when compared to PU leather. On the other hand, in the perpendicular direction, PU leathers have very high percentage elongation of 290.8 ± 1.0% when compared to sheep nappa leather, which has a value of 57.9 ± 0.6%, as shown in Table IV. The double hole stitch tear strength of PU leather is high when compared with the sheep nappa leather in both the directions. Especially, in the parallel direction, PU leathers have high stitch tear strength value of 121.7 ± 1.0 N/mm when compared to that of sheep nappa leathers that have a value of 37.9 ± 0.5 N/mm, as shown in Table IV. Although natural sheep nappa leather possesses low stitch tear strength compared to synthetic PU leather, it meets the standard requirements for use in apparel application.[22] The higher elongation and stitch tear strength of PU leathers may be due to the polyester knitted base fabric. The base fabric of synthetic leathers is generally made up of woven, nonwoven, or knitted fabrics. Among these, knitted fabrics in general are more elastic and can stretch up to 500% depending on their material and knitting pattern. Knitted fabrics in general tend to stretch in course than in wale direction. Results of this study support this reasoning.

Scanning electron microscopic analysis

The specimens cut from natural and synthetic leathers were analyzed for grain surface and cross section morphology using SEM. Scanning electron micrographs of

TABLE IV
Mechanical Properties of Natural Sheep Nappa and Synthetic PU Leathers

Leather samples		Bending length (cm)	Tensile strength (N/mm^2)	Elongation at break (%)	Stitch tear strength (double hole) (N/mm)
Sheep nappa	Parallel	2.86 ± 0.3	6.6 ± 0.6	58.0 ± 0.5	37.9 ± 0.5
	Perpendicular	3.08 ± 0.1	10.9 ± 0.4	57.9 ± 0.6	52.9 ± 0.7
PU	Parallel	2.84 ± 0.8	15.5 ± 0.3	49.7 ± 0.6	121.7 ± 1.0
	Perpendicular	2.24 ± 0.1	8.6 ± 0.4	290.8 ± 1.0	61.0 ± 0.7

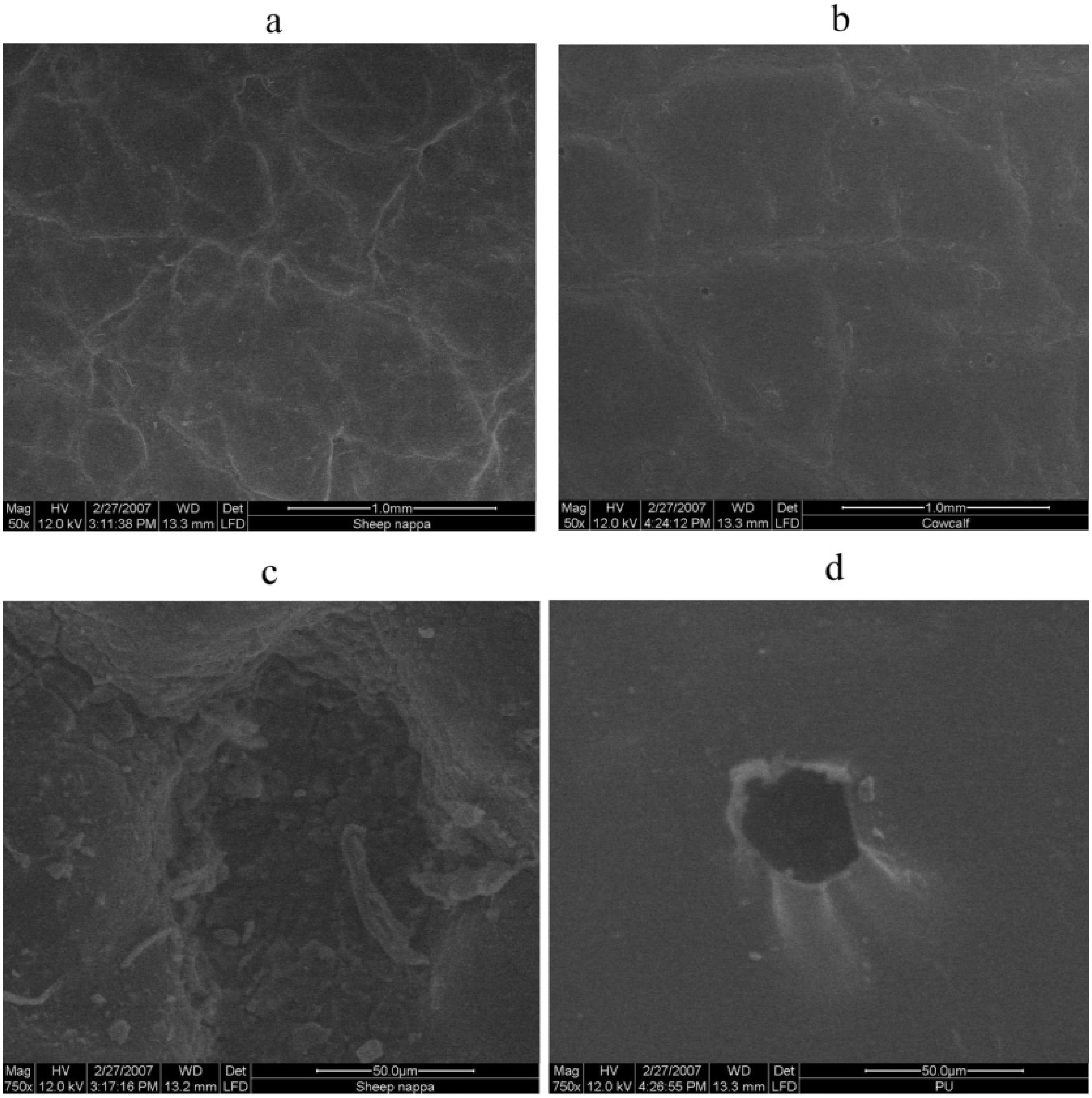

Figure 1 Scanning electron micrographs of natural sheep nappa (a and c) and synthetic PU (b and d) leathers meant for apparel showing the grain surface at lower and higher magnifications, respectively.

natural and synthetic leathers meant for apparels showing the grain surface at lower and higher magnifications are shown in Figure 1. It is seen that the natural sheep nappa leather possesses an uneven grain surface with hair pores. On the other hand, PU leather has an even surface with fairly uniform pores. The size of hair pore of natural sheep nappa leather is about 50 μm as seen in Figure 1(c). The PU leather has pores on the surface in the range of 20 to 40 μm. This value is comparable to that of previous findings.[10] Figure 2 shows cross sectional view of natural and synthetic leather specimens. It is observed that natural sheep nappa leather has fiber bundles interwoven with each other loosely and randomly throughout the leather matrix. Whereas, PU leather seems to have three layers namely PU grain layer, polyester knit intermediate layer and a polyester fluffy layer as seen in Figure 2(b). Demarcation between each layer is more clearly seen in PU leather unlike in sheep nappa leather. Magnified view of cross section of natural

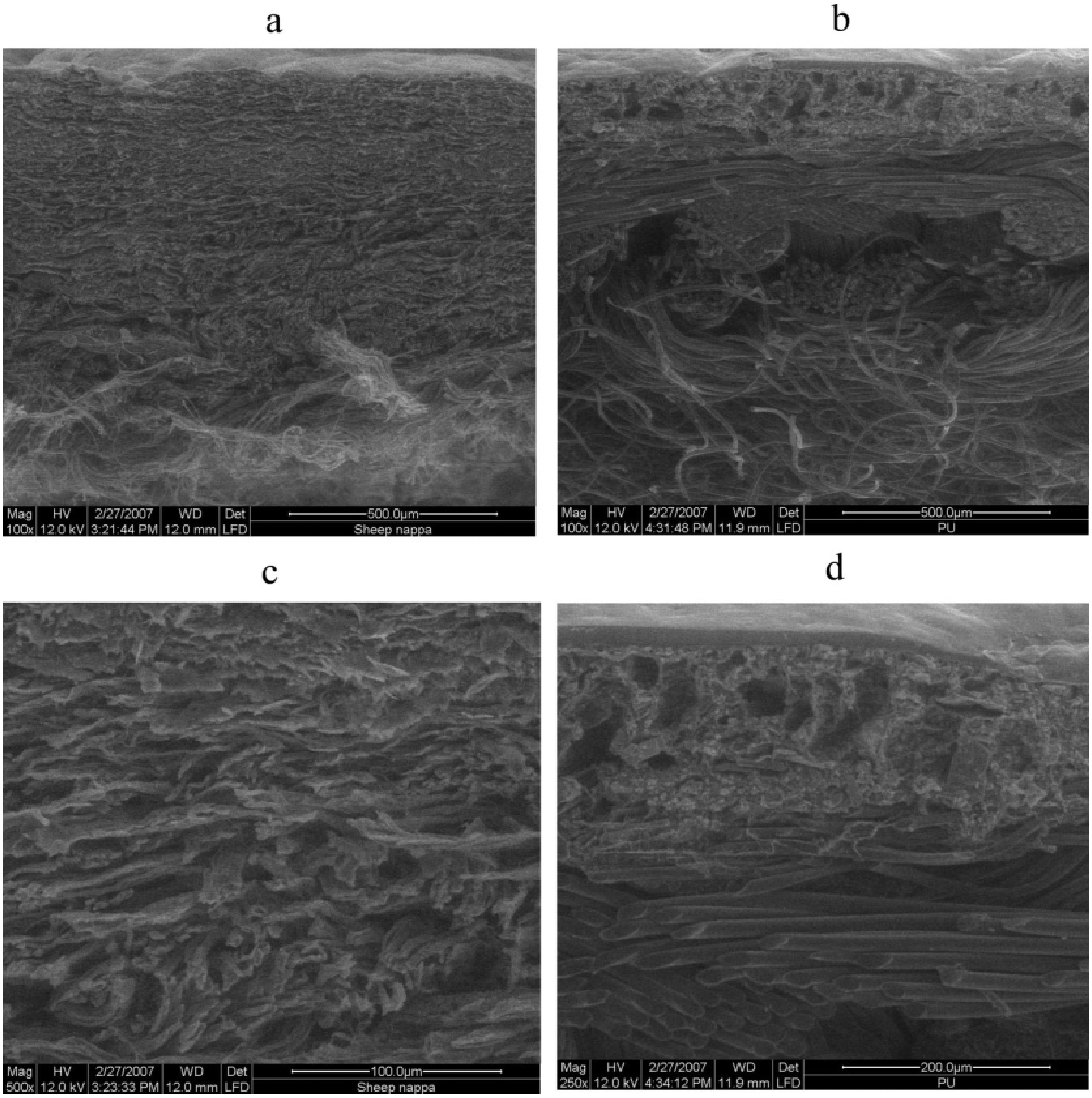

Figure 2 Scanning electron micrographs of natural sheep nappa (a and c) and synthetic PU (b and d) leathers meant for apparel showing the cross section at lower and higher magnifications, respectively.

sheep nappa leather shows a continuous porous structure with pores ranging from 5 to 20 μm as seen in Figure 2(c). These values are in good agreement with that of earlier reports.[18] The fiber bundles are running parallel to the skin surface making lesser angle of weave. On the other hand, synthetic PU leather has varying porosity in different layers as seen in Figure 2(b,d). The PU grain layer has a top continuous layer without any pores and the bottom layer has pores in the range of 20 to 50 μm. The polyester knit intermediate layer has tightly packed fiber bundles while the polyester fluffy layer consists of loosely and randomly woven fibers forming pores with sizes less than 50 μm. The lack of continuity in pore structure and the presence of nonporous top layer in the PU grain layer of synthetic PU leather are one of the probable causes for poor permeability of water vapor in comparison to the natural sheep nappa leather. These results are in good agreement with the water vapor permeability studies.

CONCLUSIONS

Leathers used for apparels must have the required comfort and physical properties. Generally, the comfort properties are associated with softness, drape, and water vapor permeability. In the present study, natural sheep nappa leather has been found to have higher water vapor permeability among all the comfort properties compared to synthetic PU leather. It is found that most of the physical properties of natural and synthetic leathers used for apparel application are direction depended and the values are comparable between natural and synthetic leathers. However, percentage elongation and stitch tear strength of PU leather are higher in specific directions when compared to natural sheep nappa leather owing to the polyester knitted base fabric in PU leather. When analyzing the chemical properties, it was found that the natural sheep nappa leathers have high moisture content, low ash content, and low pH value when compared to synthetic PU leathers. SEM analysis supports some of these results. In general, natural sheep nappa leathers seem to possess the most important comfort properties required for apparel application and hence play a vital role in the leather garment industries in comparison to synthetic leathers. Although current research efforts aim to improve the water vapor permeability of synthetic leathers, future research needs to focus on improving the comfort properties of synthetic leathers matching the natural leathers.

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