

# Leather Species Identification Based on Surface Morphological Characteristics using Image Analysis Technique

by

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## Abstract

Identification and classification of leathers based on the species becomes valuable and necessary due to concerns regarding consumer protection, product counterfeiting or authenticity issues, and dispute settlement in the leather industry and thus helping in trading standards and protecting endangered species. This is carried out mostly by microscopical examination, though, the use of DNA fingerprinting is a theoretical possibility. Identification of leather species through hair pore pattern by microscopical examination requires expertise, training and experience, and due to involvement of human judgment, subjectivity is inevitable. Recent advancements in instrumental techniques aided image analysis offers a good scope for standardizing objective criteria for species identification. In this study, an automatic recognition of leather species based on the surface hair pore pattern using image processing techniques has been investigated. The signature or distinctive feature of leathers from each of the important raw materials dealt within the leather industry were defined from SEM images using image processing technique in terms of number of hair pores, pore density, type and size of the pores (in terms of area, diameter), inter-pore distance and shape of the pore (in terms of circularity, roundness perimeter). Results of the image analysis revealed that all the four common raw materials have distinctive features in terms of specific parameters. Buffalo leather is characterized by the least pore density, largest pore (11110 sq  $\mu\text{m}$ ) and highest inter-pore distance (103sq  $\mu\text{m}$ ) whereas sheep skin has the smallest hair pore (200 sq  $\mu\text{m}$ ) with lowest porosity. Goat skin has both medium (1256 sq  $\mu\text{m}$ ) and small sized pores (364 sq  $\mu\text{m}$ ) arranged in clusters with trios pattern arrangement and cow leather is characterized by large hair pore density (2262/sq cm) with more uniform mid-sized pores (2190 sq  $\mu\text{m}$ ). Thus the developed image processing technique using the current state of art has the potential to provide quantitative estimates of the leather surface morphological characteristics in terms of quantifiable parameters to identify the animal origin.

## Introduction

Cattle hides and sheep skins are universal raw materials for the global leather sector and the availability of goat and pig skins and buffalo hides are restricted to only some countries.<sup>1</sup> There is a huge difference in the international price for leather from different species and it becomes necessary for the product manufacturers to clearly establish the type of leather. On the other hand, it has also become necessary to prevent the use of skins from endangered species for the production of leathers.<sup>2</sup> In the case of grain-on leathers, identification of the species of hide or a skin is often carried out from the grain pattern of the leather. Each species of hide or skin has characteristic features depending on the number and type of hair pores, hair density and the way they are distributed over the surface. However, there are challenges due to variation in the grain pattern depending on the breed, age, sex, etc.<sup>3-5</sup> Moreover, there may be considerable variation in the grain pattern between different locations within the skin/hide as well.<sup>6</sup> In the case of chamois leather and heavily corrected leathers, identification by microscopical examination may be difficult. There have been research efforts to establish authenticity of chamois leather by DNA finger printing techniques.<sup>7-8</sup>

Many prior studies have been done on the measurement of dimensions of hairs and density of population with major breeds in the area of veterinary science.<sup>9-14</sup> Also histological studies have been carried to identify species and its signature characteristics for major breeds, with which an experienced/trained microscopist can identify the species.<sup>15-16</sup>

Goat skin is characterized by trios arrangements of large pores surrounded by small pores in a cluster whereas hair sheep and cow hides have more or less uniform sized pores distributed uniformly throughout the grain without any perceptible cluster/group arrangement. The information about density of hair pores

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for different hides and skins is often found in literature, however the range is too vast and overlapping for different species.<sup>17-18</sup> Buffalo hide has both large and small pores and it is sparsely populated with the least number of pores per sq inch among the major species of hides and skins, usually in the range of 900-1200 per sq inch.<sup>19</sup> There is a considerable variation in the arrangement of pores between hair and wool sheep skins. Generally, wool sheep skin is characterized by cluster arrangement of fine and coarse wool. For goat<sup>6,20-21</sup> skins, the range prescribed is 9000-13000 hairs per sq inch whereas the information available for sheep<sup>22-24</sup> and cow<sup>25-26</sup> is 8000-10000 and 10000-20000 per sq inch respectively.

Despite the availability of basic information, an objective leather species identification method is yet to be developed. Advances made in the image analysis techniques can be profitably employed to identify the species of leathers unambiguously without solely relying on the expertise of the leather merchandiser or an experienced microscopist.

An attempt to develop an objective leather species identification algorithm by the application of image analysis technique to Scanning Electronic Microscopic (SEM) images for the grain surface of these four major species has been made in the present study.

### Fundamentals of Image Processing

An image can be defined as a 2D signal  $f(x,y)$  that varies over the spatial coordinates  $x$  and  $y$  where the values of the function  $f(x,y)$  represent the intensity values of the image. Image analysis is an area that concerns the extraction and analysis of object information from the image and facilitate the automatic interpretation of images.<sup>27-28</sup> The steps in automatic image analysis are:

1. Image acquisition: To obtain the digital image of the object.
2. Image enhancement: To improve the quality of the image by reducing noise due to random variation of image intensity that may appear as grains in the image and to highlight the region of interest (hair pores) for further analysis of the image.
3. Image segmentation: To divide the images into foreground (hair pores) and background (remaining leather surface) and thereby extract the region of interest (hair pores) that are necessary for feature extraction.
4. Feature extraction: Computation of image features that includes measurement of hair pores property in terms of hair pore size, hair pore density, porosity, distance between the pores, shape etc., that are necessary for species recognition.

5. Pattern recognition: Identify and recognize the hair pores that are present in the leather surface image using above image features and classify the leather origin accordingly.

The identification of leather species using image analysis involves the detection of hair pores found on the leather surface and the measurement of hair pore properties by extracting image features. The role of image segmentation algorithm and feature extraction is vital and the success of the final species recognition phase depends on these aspects. Discrimination criteria based on hair pore properties such as mean pore area, pore density, as well as inter-pore distance between the hair pores were computed using image analysis algorithms to identify the leather species. In this current investigation, image analysis technique has been used to arrive at the signature features for each species, viz., cow and buffalo hides and hair sheep and goat skins to enable automatic identification of leather species.

## Materials and Methods

### Materials

Representative leather samples of each species (20 each) with least distorted grain structure as observed in an optical microscope with a magnification of 32x were selected from the official butt portion of the crust leather samples (goat, sheep, buff and cow) for SEM analysis. MATLAB, a high level fourth generation programming language that run under the Microsoft Windows environment was used in this study. MATLAB's Image processing toolbox provides an easy platform for image visualization which involves display, manipulation and measurement of image data. All of the image analysis algorithms described in this study were implemented in MATLAB v8.1 ([www.mathworks.com](http://www.mathworks.com)).

### SEM Studies

The surface morphological characteristics of the leather samples were obtained using scanning electron microscope (SEM). The leather surface was scanned on SEM Model FEI Quanta 200 with an application of 15.0 KV at 100X magnification.

### Methods

The computational workflow for the identification of leather species is shown in Figure 2.

### Pre-Processing & Spatial Calibration

Text information related to magnification and scale present in the bottom of SEM image was taken into account for spatial calibration. The length of the known distance is measured in pixels and the calibration factor was calculated as below

Calibration factor = known distance ( $\mu\text{m}$ )/distance measured in pixels.

For example to measure area

$$\text{Area } (\mu\text{m}^2) = \text{AreaInPixels} * \text{calibration factor} ^ 2.$$

Similarly all the features/attributes extracted from the SEM image were multiplied with the calibration factor. The text information presented at the bottom of the image was removed to prevent the inclusion of the details in image processing.

### Image Enhancement

Image enhancement techniques are used to reduce high-frequency noise and low-frequency background variations in the images. Thus, the image enhancement techniques highlight hair pores in the image. In this study, to reduce the noise due to background intonations and highlight the difference between the hair pores, gradient distribution specification<sup>29</sup> image enhancement technique was used. By using this technique, the quality of the image was enhanced by gradient remapping.

### Image Segmentation

Separation of hair pores from the leather background was carried out using image segmentation algorithm. Image intensity distribution of a typical leather surface image can be considered as a combination of foreground (hair pores) and background (rest of the leather surface) objects. Hair pores present in the image are darker than the background and hence are populated at the least intensity region in the histogram whereas the background occupies larger part of the higher intensity region. The intensity value was so chosen as a threshold to include all the hair pores but eliminating the background objects. Leather being natural material, the intensity variations at few places were similar to the hair pores and hence few unwanted spots appear in the background after the segmenting the image using histogram thresholding technique. Median filtering is a technique used to reduce the intensity variations appearing in the background while preserving the hair pore edges. Image morphology<sup>30</sup> is an important tool in image processing for analyzing the shapes of the objects. Since the hair pores were basically of circular shape, disk structuring element was selected for morphological operation. The basic morphological operators

such as dilation and erosion were used to eliminate the unwanted spots thus segmenting the hair pores alone. The centroid of the hair pores were identified by repeated application of morphological erosion operation and labelled so that feature extraction can be carried out for each label.

### Feature Extraction

The area of the hair pores was estimated by computing the total number of pixels occupied by each pore i.e. region of interest (ROI). Mean, standard deviation, minimum and the maximum intensity value within the ROI were also computed. The Feret's diameter was computed as the longest distance between two parallel lines tangent to the pore. Inter-pore distance was obtained by measuring the distance between the adjacent centroids that ideally represents the centre of the pores. Hair pore density represents the number of pores in an unit area of the image. Porous area fraction or porosity was calculated as the total area occupied by the pores divided by the total area of the investigated image region.<sup>30,31</sup> Shape of the hair pore was examined in terms of circularity, aspect ratio (AR), solidity.

$$\text{Circularity} = 4 * \text{Pi} * \text{Area} / \text{Perimeter}^2$$

Circularity value of 1 indicates a perfect circle. As the value approaches 0, it indicates an increasingly elongated polygon.

Aspect Ratio (AR) was computed as a ratio of minor axis to major axis.

Solidity describes the extent to which the hair pore shape is convex or concave and defined as Area of the shape region / Convex Hull Area (H)

## Results and Discussion

The main objective of this study is to arrive at the objective criteria for automatic identification of recognize the leather species based on the hair pore pattern.

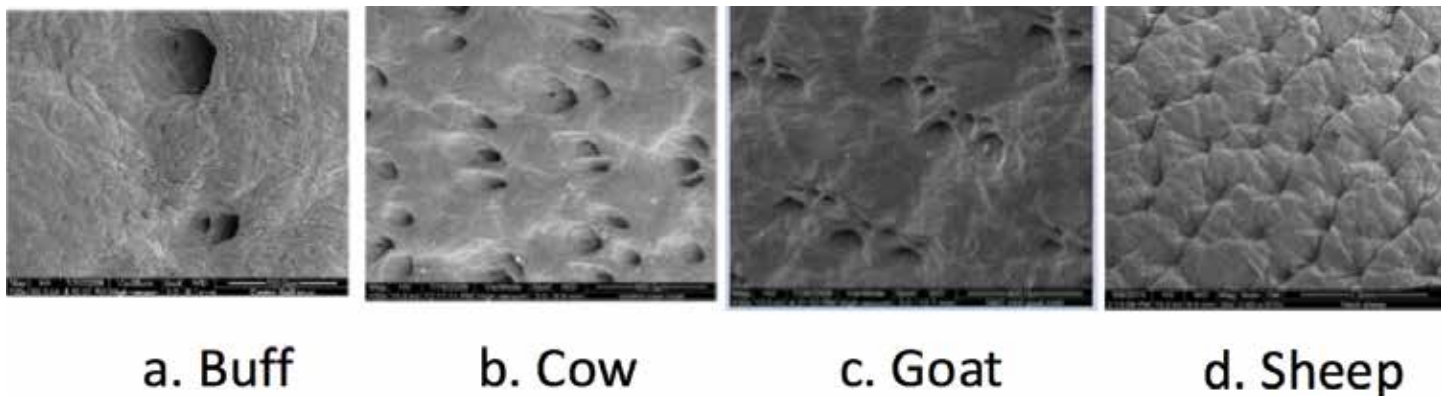


Figure 1 SEM images of leather sample.

The leather hair pore arrangement and characteristic features for the four leather species (buffalo, cow, goat and sheep) were investigated. The 20 SEM images of each species were selected in such a way that they represent a broad illustrative set to characterise each species. The typical SEM images of buffalo, cow, goat and sheep leathers are shown in Figure 1a, 1b, 1c and 1d respectively. The images were subjected to image analysis to come with characteristic features for each species based on the pore type, size and shape. Figure 2 illustrates the flow diagram for identification of leather species using image processing technique. SEM images were spatially calibrated by computing the calibration factor.

The images at different stages of segmentation process for goat leather are presented in Figure 3 as example to explain the procedure. It can be observed that the intensity distributions of the pores and the background often overlapped, thus complicating the separation of information relating to pores alone. Hence, a two-step procedure was carried out for segmenting the leather pores. First, histogram-based thresholding technique was used to separate the pores from the leather background. After this process, the leather image still had many spots apart from the hair pores as seen in Figure 3c which were undesirable for further analysis. Hence in the second phase of segmentation process, median filtering followed by morphological operations involving erosion and dilation operations were performed using disk structuring element as applicable for circular shape (Figure 3d). Finally after the two phase segmentation, the hair pores were labeled and the features corresponding to each of the labeled hair pores were analyzed using image processing technique and the results compiled. Hair

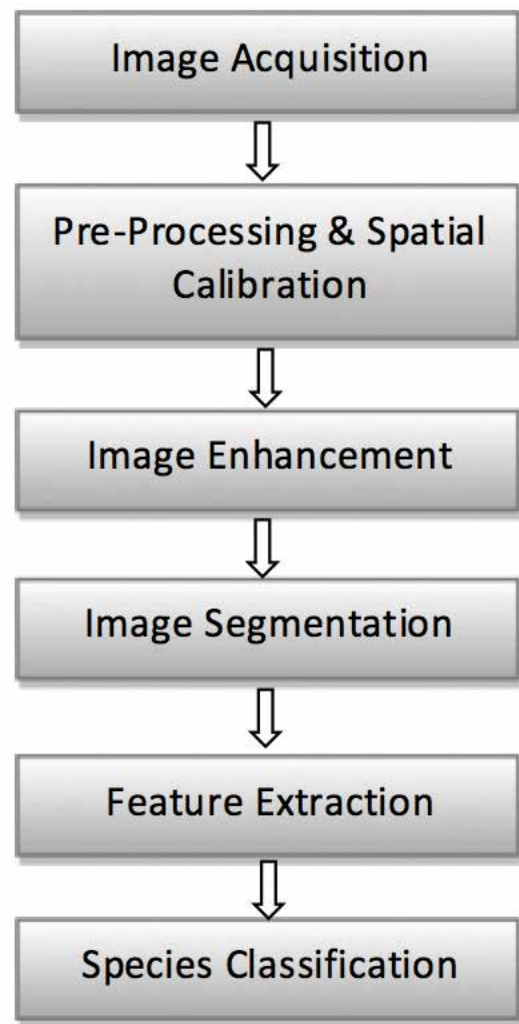


Figure 2. Flow Diagram for Leather Species Identification.

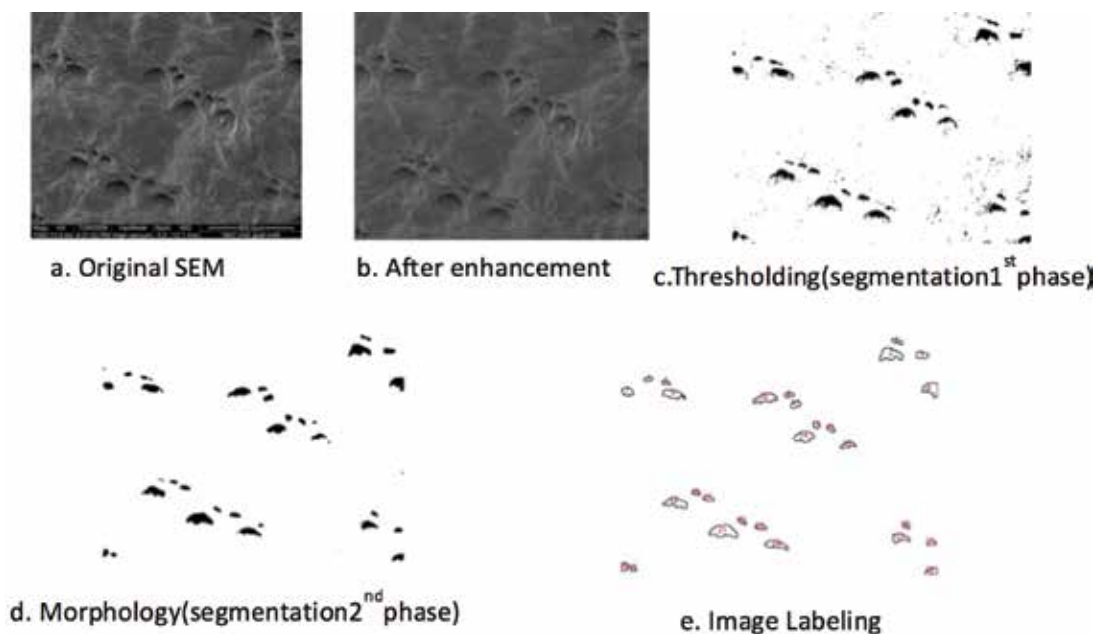


Figure 3. Images at different stages of Segmentation Process (Goat Leather).

pores were counted and classified as small ( $\leq 1000$  sq  $\mu\text{m}$ ), medium (1000 – 4000 sq  $\mu\text{m}$ ) and large ( $> 4000$  sq  $\mu\text{m}$ ) based on the area and the following features were additionally extracted for each species.

#### Mean Pore Area

Table I summarizes the data of mean pore area for the four leather species (goat, sheep, cow and buff). The mean pore area

was found to be the largest for the buffalo leather (3772.5 sq  $\mu\text{m}$ ) with leathers from cow (2051.97 sq  $\mu\text{m}$ ), goat (1256.21 sq  $\mu\text{m}$ ) and sheep (523.61 sq  $\mu\text{m}$ ) in the decreasing order. Large hair pores were found in the case of buffalo hide with largest pore about 11,000 sq  $\mu\text{m}$  but due to the presence of small pores, the average pore area gets reduced. The smallest hair pore area, about 200 sq  $\mu\text{m}$ , was recorded for sheep leathers. Hair pores in cow leathers were found to be of uniform size and mostly

**Table I**  
**Hair Pores Distribution based on Area.**

Pore Area (sq mm)					
Species	Mean	Std Dev	Min	Max	Least inter pore distance $\mu\text{m}$
Goat	1256	967	365	3988	36
Cow	2052	718	683	3545	58
Sheep	524	302	200	1181	65
Buff	3773	5032	351	11111	104

**Table II**  
**Hair Pores Distribution based on pore density.**

Pore Density (per sq cm)					
Species	Overall	Small	Medium	Large	Percent Porosity
Goat	2185	1248	936	0	0.027
Cow	2263	0	2263	0	0.046
Sheep	1099	1099	0	0	0.005
Buff	304	152	76	76	0.021

**Table III**  
**Shape Properties of Pores.**

Species	Feret diameter $\mu\text{m}$	Circularity	AR	Solidity
Goat	59	0.71	2.16	0.85
Cow	77	0.73	1.89	0.84
Sheep	39	0.67	2.01	0.81
Buff	90	0.61	2.32	0.87

classified in the medium range. Goat leathers were found to have pores in both small and medium size ranges and hence the mean pore area was less than that for cow.

#### Least Inter-pore Distance

Centroid of each hair pore was computed and the minimum distance of the adjacent hair pores were also calculated. Table I shows the least inter-pore distance for the four species. In the case of goat trios arrangement, the distance between the small pores was the least with least inter-pore distance of 35.88 $\mu$ m. Cow and sheep leathers had uniform pore distribution and the least inter-pore distances of 58.17 $\mu$ m and 64.91 $\mu$ m were recorded for them respectively. The pores were sparingly present in buffalo leathers with the highest inter-pore distance of 103.85 $\mu$ m.

#### Hair Pore Density

In this study, hair pore density was calculated from the number of pores present per sq cm. Overall hair pore density of 2262.67/sq cm and 2184.73/sq cm for cow and goat leathers were found to be almost similar (Table II) but there are differences in the size and distribution of the pores. Cow leathers have uniform pores which are in medium size range and the overall hair pore density is almost equal to the density of medium sized pores. Goat hair pores are in both small and medium ranges with density of small pores for goat leather (1242.4/sq cm) is more than that of medium sized pores (936.3/sq cm). The pore density of sheep leathers was found to be 1098.6/sq cm which is about half the pore density for goat leathers. Buffalo hair pore density of 303.88/sq.cm was found to be the least among the four species.

#### Percent Porosity / Porous Area Fraction

Porosity defines the ratio of the cumulative surface area occupied by pores to the total surface area of the leather. From Table II, it can be observed that the highest porosity was found in cow (0.046) followed by goat (0.027), buffalo (0.021) and hair sheep (0.0057) in that order. Goat and cow have similar pore density but they differ quite considerably in terms of percent porosity. Despite the lower pore density, percent porosity of buffalo leathers was found to be higher than that for sheep leathers due to the presence of larger pores.

#### Hair Pore Shape Attributes

Shape attributes of the hair pores were analysed in terms of Circularity, Aspect Ratio (AR), Solidity and Feret diameter results are presented in Table III. Circularity value of 1.0 indicates the shape to be more round, smooth as a perfect circle but the values for all the four species were in the range of 0.6 – 0.73. Aspect ratio (AR) corresponds to elongation and the values for goat, sheep and buffalo leathers were greater than 2.0 and for cow, it was 1.89. Solidity is the measurement of overall concavity of the hair pores present. It describes the extent to which the shape is convex or concave. The pores in all the four species were in the range of 0.81 – 0.85 and hence were approaching a convex shape.

Generally the hair pores would have been round in shape without elongation in any direction at the raw stage but as the material undergoes some degree of distortion due to chemical and mechanical operations during leather processing, the information relating to these parameters may not be much useful for species identification. However, this information may be exploited for understanding the effect of a particular process parameter or mechanical operation on the grain pattern.

## Conclusions

Mathematical algorithm using image processing techniques was developed to quantify the surface morphological characteristics of the leather hair pores from SEM images. Hair pore features were extracted by using mathematical morphology operators and the segmentation process. Features such as average pore-size distribution, least inter-pore distance, porosity, hair pore density and shape attributes like circularity, aspect ratio, solidity of the pores were accurately quantified by the algorithm. Buffalo leathers have the least hair density and largest pore size whereas hair sheep leathers have the smallest pores with least porosity. Cow and goat leathers have the largest pore density among the four species but cow hair pores are in medium size range distributed more uniformly whereas goat leathers have both small and medium sized pores arranged in cluster arrangement. Cow and goat leathers also differ significantly in terms of porosity. Goat leathers are also characterized by the least inter-pore distance. Thus image analysis was effectively used in defining the specific features unique to each of the leather types investigated in this study.

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## References

1. Mascianà, P.; World Statistical Compendium for raw hides and skins, leather and leather footwear, Food and agriculture organization of the United Nations, 1998-2014.
2. Wijnstekers, W.; The Evolution of CITES - 9th edition, International Council for Game and Wildlife Conservation, 2011.
3. Mir, S. A., Sathyamoorthy, O. R., Geetha, R., Balachandran, C.; Micrometrical studies on the skin of madras red sheep (*Ovis aries*) in different age groups, Tamilnadu. *J. Veterinary & Animal Sciences* 7, 23-28, 2011.

4. Abbasi, M., Gharzi, A., Karimi, H., Khosravinia, H.; Effects of sex on histological characteristics of various areas of skin in an Iranian native breed of sheep. *J. Ani. Vet. Adv.* **7**, 1503-1505, 2008.
5. Patel, J. M., Vyas, K. N., Vyas, Y. L., Dave, A. D.; Age associated changes in skin thickness and follicle and sweat gland depth in Jersey x Kankrej and Holstein x Kankrej F1 crossbreds. *Indian Vet. J.* **65**, 523-526, 1988.
6. Das, D. K., Mitra, S. K., Nayudamma, Y.; Grain quality of Indian goat skins – A histological study. *The Tanner* **18**, 107-109 and 147-151, 1963.
7. Long, A. J., Addy, V. L., Booth, S., Dwyer, R. O., Loftus, R.; Extraction of DNA from Leather and applications to the supply chain. *JALCA*, **102**(1), 22-26, 2007.
8. Stenzel, S., Bohrisch, J., Pach, M., Meyer, M.; A New Marking System for Leather Based on Encapsulated DNA. *JALCA*, **110**(9), 277-287, 2015.
9. Mc Ewan, J. D., Nay, T.; Sweat gland and hair follicle measurements as indicators of skin type in cattle. *Aust. J Biol. Sci.* **21**, 1001-1011, 1968.
10. Jenkinson, D., Mc Ewan, Nay, T.; The sweat glands and hair follicles of different species of Bovidae. *Aust. J Biol. Sci.* **28**, 55-68, 1975.
11. Al-Abbas, A. H., Abdul Raheem, M. H., Chaudhury, M. S., Hilmy, M. I.; The skin of Gazelle 1-Morphological studies. *Ann. Coll. Med. Mosul.* **5**, 113-129, 1974.
12. Ansari-Renani, H. R., Moradi, S., Baghersah, H. R., Ebadi, Z., Salehi, M., Seyed Momen, S. M., Ansari-Renani, M. Y.; Determination of Wool Follicle Characteristics of Iranian Sheep Breeds. *Asian-Aust. J. Anim. Sci.* **24**, 1173 – 1177, 2011.
13. Saxena, S. K., Malik, M. R., Parekh, H. K. B.; Histological character of skin in crossbred cattle. *Indian J. Vet. Anat.* **6**, 8-11, 1994.
14. De Marinis, A., Asprea, A.; Hair identification key of wild and domestic ungulates from southern Europe. *Wildlife Biology* **1293**, 305-320, 2006.
15. Hides, skins and leather under Microscope. BLMRA, London, 1957.
16. Trautmann, A., Fiebiger, J.; Fundamental of the histology of domestic animals. Comstock Pub Associates, Cornell University Press, New York, 1957.
17. Dutta, S.; An Introduction to the principles of leather manufacture, 4th ed. Indian Leather Technologists' Association, Calcutta, India 1985.
18. Sarkar, K.; Theory and Practice of Leather Manufacture, 1965, The Author, Calcutta, India 2005.
19. Raheem, A., Elias, M., Ahmed, N.; The correction Factor of hair density in the skin of Buffalo. *Iraqi J. Vet. Sci.* **20**, 101-106, 2006.
20. Khan, B., Talukdar, A.; Follicle population in Black Bengal goats, *The Journal of Agricultural Science* **88**(1), 251-253, 1977.
21. Raheem, A., Al-Hety, M.; Histological and morphometrical study of the skin of black goat. *Iraqi J. Vet. Sci.* **10**, 59-71, 1997.
22. Raheem, A., Al-Hety, M.; The correction Factor of hair density in the skin of Awasi sheep and black goats. *Iraqi J. Vet. Sci.* **13**, 27-31, 2000.
23. Mobini, B.; Micrometrical Studies on the Hair Follicles at different areas of skin in Iranian bakhtiari lambs. *World Applied Sciences Journal* **21**(2), 260-263, 2013.
24. Stenhagen, O., Bredenhann, A.; The effect of histological processing on sheepskin samples. *S. Afr. J. Anim. Sci.* **17**, 151-152, 1987.
25. Carter, H., Dolling, D. ; The hair Follicle and apocrine gland population of cattle. *Aust. J. Agric. Res.* **5**, 745, 1954.
26. Amakari, S.K., Hill, D.H.; Hair Follicle measurements in some tropical and temperate breeds of cattle in Nigeria. *Int. J. Biometeror.* **19**(2), 115-121, 1975.
27. Sridhar, S.; Digital Image Processing, 1st edition, Oxford University Press, New Delhi, India, 2011.
28. Gonzalez, R., Woods, R.; Digital Image Processing, 3rd edition, Pearson Prentice Hall, New Jersey, USA, 2008.
29. Gong, Y., Sbalzarini, I.; Image enhancement by gradient distribution specification. In Proc. ACCV, 12th Asian Conference on Computer Vision, Workshop on Emerging Topics in Image Enhancement and Restoration, 3-7, Singapore, November 2014.
30. Goldberger, J., Gordon, S., Greenspan, H.; Unsupervised Image-Set Clustering Using an Information Theoretic Framework. *IEEE Transactions on Image Processing* **2**, February 2006.
31. Saheb Baha, S., Prasad, K.; Automatic detection of Hard Exudates in Diabetic Retinopathy using Morphological segmentation and Fuzzy Logic *International Journal of Computer Science and Network Securit* **8** (12), 2008.
32. Ziel, R., Haus, A., Tulke, A.; Quantification of the pore size distribution (porosity profiles) in microfiltration membranes by SEM, TEM and computer image analysis. *J. Mem. Sci.* **323**(2), 241-246, 10/2008.

## Lifeline

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Few people realize that Leather Making is the world's oldest manufacturing process, thus the world's oldest industry. Tanning—the process of converting hides and skins into leather—is also the world's first science.

Also, because of the pure craftsmanship involved, tanning may well be the world's first art form.

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fibers per square inch has  
only to count them.

NOTHING TAKES THE  
PLACE OF LEATHER

#### INDEX TO ADVERTISERS

ALCA Information .....	Inside Back Cover
Biosk.....	II
Biosk.....	V
Buckman Laboratories.....	Inside Front Cover
Chemtan .....	III
Chemtan .....	Back Cover
Elementis .....	VI
Erretre .....	IV