Histological Study of the Skin and Leather Characteristics in Two Types of Arabian Camels (*Camelus dromedarius*)

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Abstract: Six growing male one-humped camels (3 Maghrabi and 3 Sudani) were used to study histological skin structure and leather characteristic. Both primary and secondary follicles dimensions were affected by breed. External diameter of primary follicle was found to be significantly (P<0.05) higher (145.85µ) in Maghrabi than in Sudani camel (115.95µ). The internal diameters of primary follicles were 86.83µ and 63.38µ in Maghrabi and Sudani camels, respectively. The wall thickness of secondary follicles was highly significant in Maghrabi (59.01µ) than Sudani (52.57µ). Fibre diameter of both primary and secondary follicles were significantly higher in Maghrabi (64.2µ vs 47.0µ) than in Sudani camel (26.8µ vs. 21.6µ). The dermis thickness was found to be 4136.77 µ in Maghrabi and 3840.07 µ in Sudani. Reticular thickness was significantly higher (3304.9 µ) in Maghrabi than in Sudani camel (3218.69 µ) while papillary thickness was significantly higher in Maghrabi (831.86 µ) than in Sudani (621.37 µ). No significant differences existed between values of leather physical properties in both camel breeds expect for tensile strength which was higher in Maghrabi (390.07 kg/cm2) than in Sudani camels (322.23 kg/cm2). Highly positive correlation coefficients of 0.95, 0.97, 0.93 and 0.99 were found between tensile strength and secondary follicles dimensions in terms of external and internal diameter as well as wall thickness and fibre diameter, respectively. The number and dimensions of primary follicles are closely related to tearing strength than those of secondary follicles. Tear strength was correlated with fibre diameter (0.78) and s/p ratio (0.77). Elongation showed highly positive correlations with the primary follicle dimensions in terms of external and internal diameter, wall thickness and fiber diameter (0.93, 0.93, 0.92 and 0.93, respectively) while had negative correlations with the corresponding values of the secondary follicle dimensions (-0.75, -0.70, -0.79 and -0.56, respectively). The present study indicated the possibility of using some camel skin characters such as primary and secondary follicle dimensions in predicting the quality of tanned leather in terms of tensil strength, tearing strength and elongation.
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1. Introduction

Camel is known to be of supreme adaptability to the harsh conditions of the desert. The Dromedary or Arabian camel (*Camelus dromedarius*) is important specie found mostly in arid and semi-arid desert conditions across the North Africa and some Arab countries. Camels represent an important source of income in Egypt in which, there is about 130.7 thousand heads producing 43 thousand tons of milk, 3500 tons of meat and 1300 tons of hides per annum (Sooud, 1995 and Kewan, 2003). The quality of camel skin is unique among the mammals' skin in terms of thickness, toughness and compactness. In addition, the translucent structure of camel hides makes them useful for making lampshades, drum leather and containers (Bhakat and Sahanni, 2005). Since little information are available on physical characteristics of camels' leather. The present study aimed to investigate the relationship between skin structures as a raw material and camel leather physical properties together with its ability for tanning.

2. Materials and Methods

The present study used six growing one-humped male camels (3 Maghrabi and 3 Sudani) of about 24 – 30 months of age with an average body weight of 401±19.5 kg and 348±19.5 kg for Sudani and Maghrabi camel, respectively at Maryout Research Station belongs to Desert Research Centre, 35 km west of Alexandria. The Maghrabi animals were chosen from the camel flock raised at Maryout Research Station while Sudani camels were bought from Barquash Market, El-Giza Governorate. Both camel groups were kept on a 4-month feeding trial where they fed on berseem hay (*ad libitum*) and supplemented with proportional amounts of concentrates. Wool and skin samples were taken from left mid-side position at the middle of the last rib 48 hours before slaughtering. All camels were fasted for 24 hours before slaughtering. Camel hides were collected and preserved by salt directly after slaughtering then transported to El-Shafei tannery located in El-Max region in Alexandria. Camel hides of each group were treated separately throughout

processing. Tanning process started with beam house steps (soaking, unhairing, deliming, bating and pickling) followed by tanning with chrome and finishing steps. Table (1) illustrates tanning steps and chemicals used with the studied camel hides.

Histological studies

The skin specimens were taken from the left mid-side position by a curved scissor with a suitable depth to represent the epidermis and dermis, and then the skin sample was fixed on foam to get flattened. Fixation was done in calcium formol for about 24 hours, and then washed and left for 24 hours in distilled water before moving the sample into 70% ethanol (Barker, 1958). Skin specimens were then dehydrated in an ascending series of ethanol (30 minutes in each of 70%, 80% and 90% ethanol and finally two changes each for 15 minutes in absolute ethanol). The specimens were cleared in benzene for about 30 minutes, infiltrated in paraffin wax of a melting point of 60^{o} C (4 changes, 20 minutes each) and then embedded in the same paraffin to prepare the blocks. Vertical and transverse sections (6-8 microns in thickness) were prepared for histological studies.

For general histological observations of the hair follicles and their appendages, skin sections were stained by Haematoxylin and Eosin stain (Drury and Wallington, 1980). The stained sections were used to measure the dermis thickness. The follicle groups were counted and the secondary to primary follicles ratio (S/P ratio) was estimated in ten follicle groups for each skin samples taken from the experimental animals.

Leather physical properties:

After tanning process, all tanned leathers were tested physically according to ASTM-D1610 (2010) to determine its quality using Tinius Olsen benchtop tester (5KN capacity) apparatus to determine skin physical properties in terms of thickness (ASTM - D1814), tensil strength (ASTM-D2209), elongation (ASTM-D2209) and tongue tear strength (ASTM-D4704).

Data was analyzed using IBM SPSS 2012 program version, 20.

Table (1). Executed recipe for tanning Maghrabi and Sudani camel hides

Step	Description		Time (min)	Notes
	%	Added		
Soaking	300	Water	180	
Liming & Unharing	80	Water	60 then Overnight	• pH= 13. • Drum speed 1cyc./min. • Check hair roots before next step. • Fleshing before next step.
	3	Lime		
	1	Sodium sulphide		
Washing	300	Water	30	Repeated until water became clear
sDeliming & Bating	150	Water	60	• pH= 8. • Check before next step. • Drum speed 3 cyc./min.
	1.5	Ammonium sulphate		
	0.25	Orpone bate (pancreatic enzyme)		
Washing	200	Water	30	
Pickling	150	Water	90	• pH= 3.5. • Bé = 8. • Drum speed 3 cyc./min. • Shaving after pickling to 1.2 thickness.
	10	Salt		
	X	Sulphuric acid		
	0.5	Formic acid		
Tanning	4	Chrome 33	180	• Drum speed 5 cyc./min. • Check penetration before adding magnesium oxide. • pH = 4.2.
	2	Magnesium oxide	360 then over night	
Washing	200	Water	10	Out & hourse up for 3 days.
Naturalization	100	Water	60	pH = 6
	2	Sodium bicarbonate		
Dying	3	Dye	90	Check penetration before next step.
Fatliquoring	150	Water	90	Check fatliqour in float before next step.
	8	Fatliqour (fish oil)		
Fixation	1	Formic acid	30	Check dye in float before next step.
	2	Formic acid	60	
Washing	100	Water	5	• Out. • Overnight as hourse up. • Samming and drying.

3. Results and Discussions

Figure (1) showed that camel skin consists of epidermis and dermis, in which their structure is similar to that of other mammals while the structure and distribution of the glands together with the arrangement of hairs and their follicles differ from that described for other mammals. There are two main types of hair follicles in the skin of camels, primary and secondary follicles. The primaries are usually the largest and are arranged in rows often of three primaries each. The secondaries are more numerous and lie to one side of the primaries. The hair follicle group consists of three primary follicles associated with secondary follicles (Fig. 1). There was variable numbers of primary follicles in the hair follicle group as seen from Fig. (2) in which the follicle group has four primary follicles. The difference between primary and secondary follicles is illustrated in Fig (2) in which primaries have a sweat gland and erector muscle while secondaries have neither of these. Both types have sebaceous glands. Kamel *et al.* (1986) showed that all follicle groups in camel skin have only one primary follicle. On the other hand, Lee and Schmidt-Nielsen (1962) described only two follicle groups having two or three primaries in camel skin. Abdou *et al.* (2006) illustrated that most of follicle groups are composed of trio groups which contains three primary follicles and a variable number of secondaries. Similar observations were reported in Indian camels (Mara and Khalil, 2000). About 70% of follicles groups consisted of three primary follicles while the remainder 30% of follicle groups contained 2, 4 or more primary follicles in Iranian one –humped camels (Ansari-Renani, 2008). More than three primary follicles per follicle group means that more sweat glands which might be suitable for heat dissipation and better thermoregulation, particularly in hot climate (*Abdou et., al.,* 2006).

In the present study, number of secondary (s) and primary (p) follicles were counted and the s/p ratio was counted in 20 follicle groups in each sample. Table (2) showed that the S/P ratio was 5.4 and 4.02 in Magrabi and Sudani camel, respectively, with no significant breed effects. Solouma (1992) showed that s/p ranged from 3.6 to 6.4 in different body regions of the Egyptian camel. However, s/p ratio in different regions of the Saudi Arabian camels ranged from 3.2 to 7.4 (Mahgoub *et al.,* 1999). In Iranian camel, the s/p ratio was found to be 6.3 (Ansari-Renani *et al.,* 2010). There is a significant increase in the values of s/p ratio as the level of supplementary feeding increased (Abdou *et al.,* 2006). The changes of s/p ratio were attributed to the time as being to seasonal changes must be postulated to disappearance and reappearance of secondary follicles (Burns, 1949).

Figure (3) showed a sign of branching in secondary follicles growing more than one hair from the same follicle pore. The development of the secondary follicles occurred as a result of the later secondaries derived by branching from the original ones (Hardy and Lyne, 1956). This result might occur by the fusion of the external root sheath that surrounded more than one hair that protruded from the same pore.

In the present study both primary and secondary follicles dimensions were affected by breed (Table, 2). External diameter of primary follicle was found to be significantly higher (145.85µ) in Maghrabi than in Sudani camel (115.95µ). The internal diameters were 86.83µ and 63.38µ in Maghrabi and Sudani camels, respectively. The wall thickness was highly significant in Maghrabi (59.01µ) than Sudani (52.57µ). The dimensions of secondary follicle had highly significant breed effect as shown in table (2). Abdou *et al*. (2006) found that external diameter of primary follicles ranged from 78.5 to 93.3 µm and ranged from 46.5 to 52.9 for secondary follicles from 6 to 18 months of age. In camels of Shalaten, both primary and secondary follicles dimensions were affected by different levels of nutrition (Abdou *et al.,* 2006). Elsayed and Abou Elezz (1999) pointed out that the external and internal diameters of both primary and secondary follicles of camels were higher in summer than in winter season, the differences were not significant except for internal diameter of the secondary follicles.

Fibre diameter as presented in Table (2) showed that fibre diameter of both primary and secondary follicles are highly significant in Maghrabi (64.2µ vs 47.0µ) than Sudani camel (26.8µ vs. 21.6µ). Abdou *et al.* (2006) showed that fibre diameter of primary follicles in camel was 42.6µ whereas that of secondary follicles was 22.6µ. The mean of fibre diameter was found to be 18.98±1.64 µ in Iranian camel, 21.2 µ in Dromedary camel and 18.0 µ in Bactrian camel (Ansari-Renani *et al.,* 2008). In Saudi Arabian camel, Mahgoub *et al.* (1999) estimated the thickest (60-66 µ) and the finest (45-51 µ) of primary hair fibre as well as the secondary hair fibre diameter (32 µ).

The present study showed that the thickness of epidermis, dermis, papillary and reticular were 28.06 µ, 3345.31 µ, 831.86 µ and 3304.9 µ, respectively in Maghrabi camels. The corresponding values in Sudani camels were 27.02 µ, 3840.07 µ, 621.37 µ and 3218.69 µ, respectively. Kasem (2009) concluded that the dermis thickness which had deeper follicles and thick dermis produced strong skins with higher value of tensile strength.

Thickness of epidermis and dermis (papillary and reticular) were estimated (Table 3) in which reticular thickness and papillary thickness were significantly higher (3304.9 µ and 831.86 µ) in Maghrabi than in Sudani camel (3218.69 µ and 621.37 µ), respectively. The dermis thickness was found to be 4136.77 µ in Maghrabi and 3840.07 µ in Sudani. In Barki sheep, the dermis thickness was estimated as 697.27 µ (Shedeed, 2005), 1496.25 µ (Kasem, 2009) and 2035 µ (Kotb, 1987).

Table (4) show average values for some leather physical properties. No significant differences existed between values of leather physical properties in both camel groups except for tensile strength which is the widely used measure defined as the greatest longitudinal stress on a substance which can be stand without tearing apart. The average tensile strength in Maghrabi camel was greater (390.07 kg/cm^2) than Sudani camels (322.23 kg/cm^2), the difference was not significant. This might be due to the reticular layer thickness in which collagen fibrers density tend to increase in Maghrabi than Sudani tanned leathers (Figures 4 and 5). Tensil strength was estimated in camel's leather (109.69 kg/cm^2, Azzam and Abdelsalam, 2004), in Barki sheep skin (100.6 kg/cm^2, Kasem, 2009), in abo-dleek sheep skin (126.53 kg/cm^2, Azzam, 2003; 171.33 kg/cm^2, Shedeed, 2005) and in Dromedary and Bactrian Dromedary crossbred camels (214.7 and 203.6 kg/cm^2, respectively, Salhei *et al.*, 2013).

Highly positive correlation coefficients of 0.95, 0.97, 0.93 and 0.99 were found between tensile strength and secondary follicles dimensions in terms of external, internal diameter, wall thickness and fibre diameter, respectively. These correlations were not significant except for fibre diameter ($P<0.05$) (table, 5). This result indicates that the tensile strength is associated with large follicle dimensions and coarse fibres. On the other hand, tensil strength was found to be associated more with the reticular layer (0.81) than papillary layer (0.50) (Table, 5). This result is in agreement with Kasem (2009) who reported, in Barki sheep, that the group of smaller ratio of follicles area or dimensions had lower tensile strength compared with that group of higher ratio of follicles dimensions as a result of the web of fibre waves of collagenous fibre and reticular web which maximize the skin of the native sheep or coarse wool breeds than fine wool breeds. Similar results were reported by Oliveira *et al.* (2007). In general, tensile strength was affected by dermis thickness since the thick dermis produced strong skins with higher value of tensile strength (Kasem, 2009).

Tear resistance (stitch tear resistance) as a load which makes a crack in a specimen hole were 68.14 kg/cm^2 in Maghrabi camel and 70.57 kg/cm^2 in Sudani camel with no significant difference. The relationship between tearing strength with histological structures of skin regarding the primary follicle dimensions were 0.93, 0.93, 0.94 and 0.93 for external, internal diameter, wall thickness and fiber diameter, respectively (Table, 5). It is indicated that the number and dimensions of primary follicles will be more related for tearing strength more than secondary follicles. Tear strength was correlated with fibre diameter (0.78) and s/p ratio (0.77). Azzam (2003) reported that tearing resistance is depending on collagen crosslink like tensile strength and found positive relation between tensile strength and tearing resistance. In Barki sheep, tear resistance was found to be 46.09 kg/cm^2 (Kasem, 2009) and 41.93 kg/cm^2 (Naser, 2005, while reported to be 59.73kg/cm^2 in camel leathers (Azzam and Abdelsalam, 2004) and 7.9 and 7.3 kg/cm^2 in different fine wool sheep breeds (Khamitsoev *et al.*, 1984).

Average elongation was 83.84 % in Maghrabi camel and 84.86% in Sudani one. Elongation showed highly positive correlations with the primary follicle dimensions in terms of external, internal diameter, wall thickness and fiber diameter (0.93, 0.93, 0.92 and 0.93, respectively), while had negative correlations with the corresponding values of the secondary follicle dimensions (-0.75, -0.70, -0.79 and -0.56, respectively), these correlations were not significant (Table, 5). These results were in agreement with Kasem (2009) who reported positive correlations of leather elongation with primary follicle dimensions (0.36, $p<0.01$) and dermis thickness (0.95, $p<0.01$) while negative correlations with secondary follicle area (-0.184). Leather elongation was estimated in Barki sheep (56.36%, Naser, 2011; 50.39%, Kasem, 2009), Abo-dleak sheep (60.49%, Naser, 2011), dromedary and Bactrian dromedary crossbred camels (61.0% and 63.4%, respectively, Salhei *et al.*, 2013) and in camel leather (17.00%, Azzam and Abdelsalam, 2004).

In leather tanning, skins and hides are exposed to different chemical treatments which change its chemical and physical properties (BASF, 2007 and Anthony, 2011). Heidmann (1993) explains that in beamhouse stage epidermis layer is removed after liming and unhairing step but dermis layer is remained without hair fatty substances, globular proteins. In finished leathers collagen fibres are mainly found in reticular layer. Differences between leather properties seemed to be a result of collagen fibers which differs in its woven and crosslink with added chemicals used in tanning such as chrome and fatliquers (Nasr, 2011).

Table (2): least square means (± SE) of external diameter, internal diameter, wall thickness and fibre diameter of the primary and secondary follicles

Items		Maghrabi	Sudan
Primary follicles	External diameter	145.85±7.331**	115.95±3.544
	Internal diameter	86.83±4.159	63.38±2.399
	Wall thickness	59.01±3.782**	52.57±1.398
	Fibre diameter	64.27±3.508**	47.08±1.898
Secondary follicles	External diameter	88.07±2.275**	70.01±1.462
	Internal diameter	44.50±1.073**	35.75±0.763
	Wall thickness	43.56±1.427**	34.26±0.844
	Fibre diameter	26.87±0.635**	21.63±0.413
S/P ratio		5.41±0.218	4.02±0.244

Means within the same raw differ significantly at * (P<0.05) and ** (P<0.01).

Table (3): least square means (± SE) of deferent skin layers thickness (epithelium, dermis, papillary and reticular)

Items	Maghrabi	Sudan
Epidermis thickness	28.06±1.425**	27.02±0.892
Dermis thickness	3345.31±37.775	3840.07±49.438
Papillary thickness	831.86±11.926*	621.37±16.159
Reticular thickness	3304.90±71.952**	3218.69±38.797

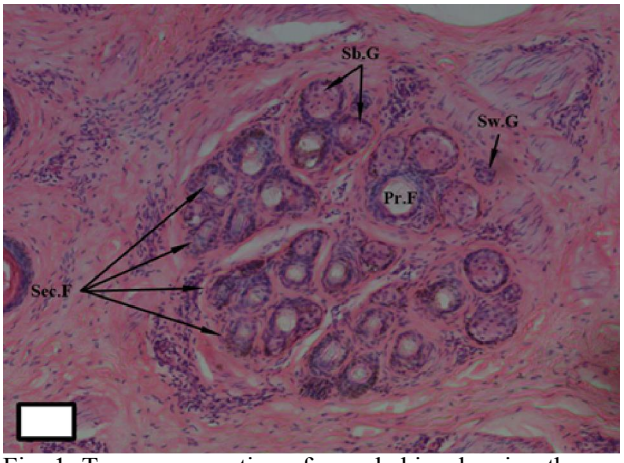
Means within the same raw differ significantly at * (P<0.05) and ** (P<0.01).

Table (4): Least square means (± SE) of leather tensile strength, elongation and tear resistance

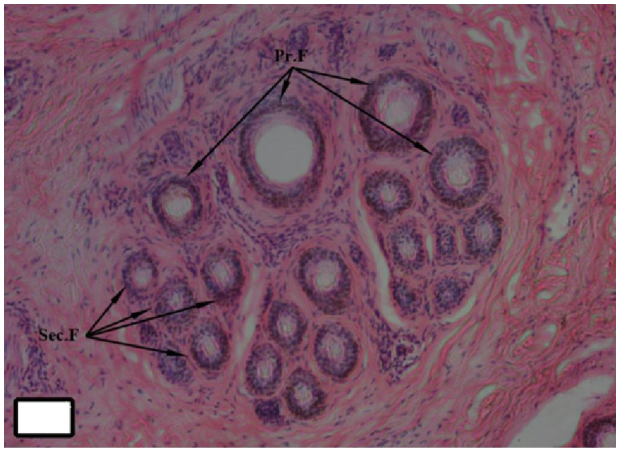
Items	Maghrabi	Sudan
Tensile strength	390.07±29.471	322.23±33.238
Elongation	83.84±3.059	84.86±2.615
Tear resistance	68.14±3.852	70.57±4.700

Table (5): Correlation coefficients between some histological structures and some leather physical properties

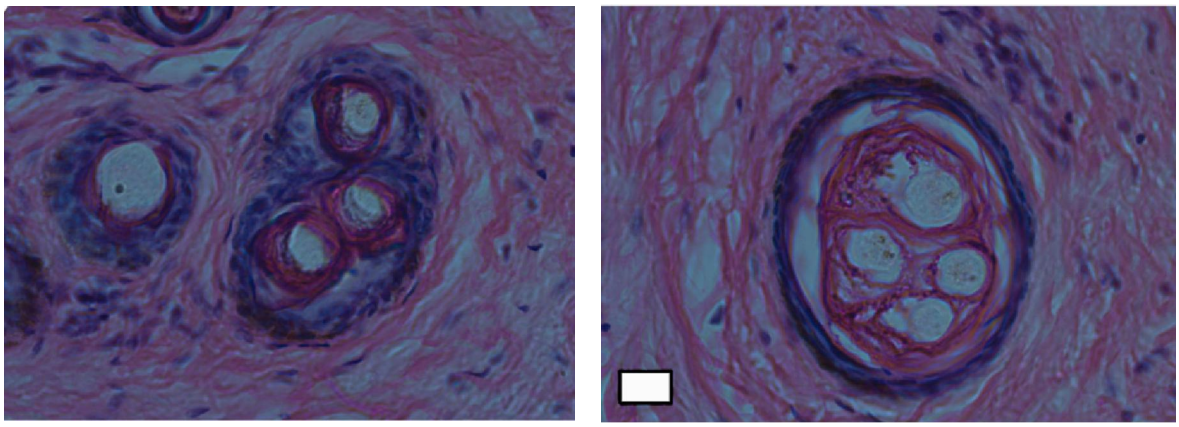
		Correlation coefficient		
		Tensile strength	Elongation	Tear resistance
Primary follicles dimensions	External	**-0.176**	**0.933**	**0.932**
	Internal	**-0.180**	**0.934**	**0.931**
	Wall thickness	**-0.157**	**0.926**	**0.939**
	Fibre diameter	**-0.170**	**0.931**	**0.934**
Secondary follicles dimensions	External	**0.951**	**-0.757**	**-0.120**
	Internal	**0.973**	**-0.700**	**-0.038**
	Wall thickness	**0.933**	**-0.792**	**-0.174**
	Fibre diameter	**0.998***	**-0.566**	**0.136**
S/P ratio		**0.717**	**0.158**	**0.774**
Fibre diameter		**0.024**	**-0.003**	**0.783**
Skin layer thickness	Dermis	**-0.313**	**0.956***	**0.673**
	Papillary layer	**0.500**	**-0.147**	**-0.291**
	Reticular layer	**0.810**	**-0.276**	**-0.035**



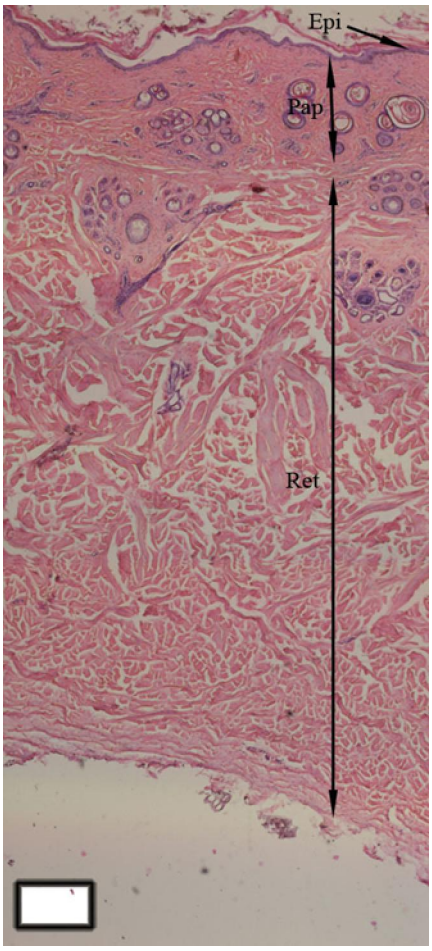
Fig, 1: Transverse section of camel skin, showing the difference between primary and secondary follicles. (HX.E.X100)



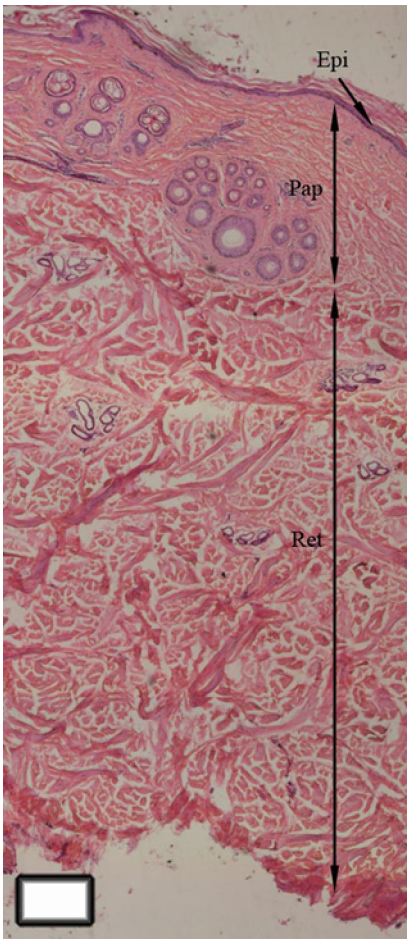
Fig, 2: Transverse section of camel skin showing follicle group containing four primary follicles. (HX.E.X100)



Fig, 3: T.S. in Camel skin showing more than one hair protruding from the same pore (arrows)



Fig, 4 : Vertical section of Maghrabi's camel skin showing the different layers of the skin (Epi) epithelium, (Pap) papillary layer and (Ret) Reticular Layer



Fig, 5 : Vertical section of Sudan's camel skin showing the different layers of the skin (Epi) epithelium, (Pap) papillary layer and (Ret) Reticular Layer

Conclusion

The present study indicated the possibility of using some camel skin characters such as primary and secondary follicle dimensions in predicting the quality of tanned leather in terms of tensil strength, tearing strength and elongation. Further studies using larger set of data are required to validate these results

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