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Evaluation of Sudanese Arabi Camel Hides for Leathers Manufacturing

Hafiz Ahmed Ali Hamed and Mohammed Alhadi Ebrahiem*

Department of Animal Production, Faculty of Natural Resources and Environmental Studies, University of Kordofan, Sudan

***Corresponding Author:** Mohammed Alhadi Ebrahiem, Department of Animal Production, Faculty of Natural Resources and Environmental Studies, University of Kordofan, Sudan.

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Abstract

This study was designed to evaluate camel hide's leather physical and chemical characteristics for leather manufacturing. For study purpose thirty pieces of fresh camel hides were obtained from slaughterhouse in the three seasons of the year (winter, summer and autumn). Ten pieces at each season of entire male Arabi camel on an average age of 3 - 4 years were collected, storing and tanned. Randomized Complete Block Design (RCBD) was used for data analysis. The results revealed that, camel leather physical quality elongation, flexibility, resistance to grain cracking and tear strength were below the minimum threshold of Sudanese, Indian and Europe standards specification for cattle leather. On the other hand average tensile strength, breaking load, double holes tear strength and camel leather chemical quality parameters (Moisture, Ash, chrome oxide and fat) were in and above the minimum threshold of Sudanese, Indian and Europe standards specification for cattle leather.

Keywords: *Sudanese Arabi Camel; Leather Physical and Chemical Characteristics; Leather Quality; Leather Manufacturing*

Introduction

Sudan has nearly three million camels, the second- largest national herd in the world, after Somalia's [1]. Tribal groups in Sudan breed distinctive types of camels [33], the well -known among these are the Anafi and Bishareen. Camels are the backbone of the Rashaida pastoralists' economy and are also central part of their culture. Cash is received at town markets for male camels sold for slaughter at the age of six to seven years. They are collected at regular intervals from the large herds and driven to the meat markets in Egypt. The live camel trade is gradually increasing in number with most going on hoof to Egypt and Libya. The greater part of Sudan's trade with Egypt used to be in camel trade, which has been for years conducted by a number of Sudanese traders. The camel has played a conspicuous and extremely significant role in the development of Sudanese communities whose natural environment has allowed of it chance for adaptation [2].

The camel farming is mainly traditional based on the mobility of the herd. The camel belt in Sudan includes the states of North and South - Darfur, North and South- Kordofan, Khartoum, Gezira, Kassala, Red Sea, River -Nile, Northern Sudan, White Nile, Blue Nile and Sennar State [3]. The Butana plains, where this study was conducted, occupy the area lying between the River Nile in the West and the Atbara River in the east. In Butana area of Sudan camels are commonly raised under nomadic conditions in a geographical zone which lies approximately between latitude 14 - 16 N and longitude 33 -36 E [2]. The total area is about 120 000 km^2. The Butana plains are inhabited by transhumant camel owning Sudanese tribes such as the Shukriya, Lahawiyin, Kawahla and Rashaida [4].

Sudan ranked the second largest national herd in the world. Although the full potential of the camel leather sector has not been realized and camel hides were not exploited due to neglect of the species, big loss in the supply chain and poor quality of hides associated with poor curing, flaying methods and tanning among other problems. Therefore, this trail aims to evaluate camel hide's leather physical and chemical characteristics (quality) for leather manufacturing.

Materials and Methods

The study area

El Obeid city is located in North Kordofan State between longitudes $21^{0}:32^{-}:20^{=}$ and $56^{0}:36^{-}$ East and latitudes $16^{0}:16^{-}:36^{=}$ and $12^{0}:14^{-}$ North. El Obeid is the political and administrative capital of North Kordofan State, which has an estimated area of 244,700 km^2. Administratively, it is divided into eight localities, namely Shikan, Al Rahad, Umruwaba, Udam Haj Ahmed, Bara, Sodry and Gabrat El Sheikh [5]. North Kordofan State is characterized by the vastness lands covered by sand dunes in the northern parts of the state. Muddy lands are found in the southern parts of the state. In the central parts the lands of Qardoud are found which is a loamy land or a mixture land of sand and mud [5]. El Obeid is located in the semi-desert zone, where the rainy season extended from July to October of each year. Precipitation is related to the movement of the tropical separator north and south. Rain and its quantity gradually decrease from north to south, where the amount of rain increases from 250 mm/year in the northern regions to reach the amount of 300 mm/year in the southern regions. El-Obeid city is affected by the northwest winds in the winter, and also by the southeast winds movement in the autumn season. The highest temperatures in El Obeid are about 44°C, and the lowest is about 10 - 13°C. The period from April to July, in addition to October, is characterized by the highest temperatures of 40 - 46°C [5].

Fresh camel hides collections for the experiment

Thirty pieces of fresh camel hides were obtained from slaughterhouse in the three seasons of the year (winter, summer and autumn). Ten pieces at each season of entire male Arabi camel on an average age of 3 - 4 years were collected and storage using salt adding technique.

Tanning procedures

Curing

Collected camel hides were cured with salt. Curing is employed to prevent putrefaction of the protein substance (collagen) from bacterial growth during the time lag that might occur from procuring the hide to when it is processed. Curing removes excess water from the hides using a difference in osmotic pressure. The moisture content of hide gets greatly reduced. Generally speaking, curing substantially reduces the chance of spoilage by bacteria. Curing was also done by preserving the hides at a very low temperature.

Beamhouse operations

The steps in the production of leather between curing and tanning are collectively referred to as beamhouse operations. They include, in order, soaking, liming, removal of extraneous tissues (unhairing, scudding, and fleshing), deliming, bating (including puering) and pickling.

Soaking

In the process known as soaking, the hides were soaked in clean water to remove the salt left over from curing and increase the moisture so that the hide can be further treated.

Unhairing

Unhairing agents used were Sodium sulfide and added as 4% of soaked hides weight divided in two paths. The majority of hair is then removed mechanically, initially with a machine and then by hand using a dull knife, a process known as scudding.

Liming

After unhairing, the hides were taken for liming: treatment with milk of lime (a basic agent) that may involve the addition of "sharpening agents" (disulfide reducing agents) calcium hydroxide ($Ca\ OH_2$) was used for this purpose and added as 3.5% of soaked hide's weight. The objectives of this operation were mainly to:

- Remove the hairs, nails and other keratinous matter.
- Remove some of the interfibrillary soluble proteins like mucins.
- Swell up and split up the fibres to the desired extent.
- Remove the natural grease and fats to some extent.
- Bring the collagen in the hide to a proper condition for satisfactory tannage.

Deliming and bating

The pH of the collagen is brought down to a lower level (from about 12 to 8) using ammonium sulfate and added as 2 - 4% of soaked hides weight, so that enzymes may act on it, in a process is known as deliming. Depending on the end use of the leather, hiedes may be treated with enzymes to soften them, a process called bating. For this process 0.5% of delimimg Zymex-R (Alkaline bating Agent) was added.

Pickling

Once bating is complete, the hides are treated with a mixture of common table salt (6%) and sulfuric acid (3%), in case a mineral tanning is to be done. This is done to bring down the pH of collagen to a very low level (from about 8 to 2.8) so as to facilitate the penetration of mineral tanning agent into the hide substance. This process is known as pickling. The common salt (sodium chloride) penetrates the hide twice as fast as the acid and checks the ill effect of sudden drop of pH.

Mineral tanning

Prior to the introduction of the basic chromium species in tanning, several steps are required to produce a tanned skin. These steps include scudding, or removing the hair, liming, or the introduction of alkali agents such as sodium hydroxide, deliming, or restoring neutral pH, bating, or softening the skin with enzymes, and pickling, or lowering pH of the hide with salt and sulfuric acid. The pH is very acidic (2.8) when the chromium is introduced as 6 - 8% of bating hides weight to ensure that the chromium complexes are small enough to fit in between the fibers and residues of the collagen. Once the desired level of penetration of chrome into the substance is achieved, the pH of the material is raised again to facilitate the process. This step is known as "basification" for this process 1% of sodium bicarbonate was used. In the raw state chrome tanned hides are blue and therefore referred to as "wet blue." Chrome tanning is faster than vegetable tanning (less than a day for this part of the process) and produces a stretchable leather which is excellent for use in handbags and garments.

Vegetable tanning

Vegetable tanning uses tannin (this is the origin of the name of the process). The tannins (a class of polyphenol astringent chemical) occur naturally in the bark and leaves of many plants. Tannins bind to the collagen proteins in the hide and coat them causing them to become less water-soluble, and more resistant to bacterial attack. The process also causes the hide to become more flexible. For vegetable tanning 6% sulphurs oil, 6% mimosa, 1% Chrome sulfate, 6% *Acacica nilotica* pods (Garad) and 3% syntan were added respectively. Hides were then stretched on frames to allow them dry straightly and to be ready for leather quality testing (physio-chemical).

Experiment tanning procedures

Process	Water %	Chemical material	Chemical %	Time	Ph
1-Socking	300	Common water		14-16 hrs	
2-Unhairing	100	Sodium Sulfide	2	90 min	
		Sodium Sulfide	2	90 min	
3-Liming	80	Calcium hydroxide	3.5	12 hrs	
5-Deliming	100	Ammonium sulfide	1	1h	
		Ammonium sulfide	1	1h	8
6-Bating		Orbon (Zymex-R)	0.5	30min	
7-Pickling	80	Sulfuric acid	1.5	15min	2.8-3
8-Tanning		Chrome	3	2hrs	
		Chrome	3	2hrs	
		Chrome	1	2hrs	
9-Fixation	100	Sodium by carbonate	1.5	30min	3.8-4
10-Retanning		Chrome sulfate	1	1h	
		Sodium by carbonate	1	30min	
		Fat pellasto xr	4	1h	
		Fat	6	1h	
		Memosa	6	1h	
		Acacia seyal pods (Garad)	6	1h	
		Syantan	3	1h	

Physical and chemical tests

Sampling

For chemical tests and to represent all the under testing samples; a composite samples were taken from three locations upon the skin. With a sharp knife samples were separately cut and mixed thoroughly. An equal weight of these cuttings from each of the samples were taken and again mixed thoroughly [6,7].

The finished leather physico-mechanical testing was taken according to the guidelines of [8,35]. Triplicate samples were taken from each skin parallel (horizontal) or perpendicular (vertical) to the backbone prior to physico-mechanical testing and sampling site were determined in accordance to [9,10].

The test specimens were cut with a steel press knife. In cutting the specimen, the knife was applied to the grain side. Then the specimens were conditioned for 48 hours in a desiccator containing silica jell at the bottom before testing both for chemical analysis and physical testing in accordance to [9,10].

Physical tests

Tensile strength test

According to [11-13] tensile strength is the force required to rupture a leather specimen of unit cross sectional area. It is determined with the tensile tester or Tensometer.

$$\text{Tensile strength, Kg /cm} = \frac{\text{Breaking load in Kg}}{\text{Cross sectional area in sq. cm.}}$$

$$\text{Cross sectional area (cm}^2\text{)} = \text{Thickness (cm) X 2}$$

$$\text{Elongation at break \%} = \frac{\text{Elongation (mm) X 100}}{\text{Specimen long (mm)}}$$

Tensile strength is thus the combined breaking strength of all the fibers taking part to fight against the applied load in a tensometer.

Flexibility test

The conditions of leather were separately studied after flexing the test specimen in a flexometer till crack develops. Changes and developments on the leather specimen were determined and recorded at 100,000 movements or lap. This test gives an idea about the future life of the leather and its performance as a shoe or as a leather article [14-16].

Measurement of tearing load

By use of a press knife six specimen were cut from the official sampling position, half of them were perpendicular and the others is parallel to the backbone. The specimen was cut by pressing the press knife through from the grain to the flesh side. The specimen pulled apart when hanged on tensile strength machine having a uniform speed of separation jaws of 100 ± 20mm. per minute, and then reading of load were recorded. Average was taken from the six readings to represent one sample and the test was repeated for other samples [8,17,18].

Measurement of resistance to grain cracking and braking load

Six (6) specimens were taken rectangles 2.5 mm in width, half of them were perpendicular and the others are parallel to the backbone. Their thicknesses were measured. The principle of the test is to observe whether the leather cracks when bent, grain outwards, around a mandrel of known diameter, the forces applied to the leather in bending it being the smallest that are required to maintain the leather and mandrel in contact. The apparatus shall include a clamp or other device which rigidly holes one end of the specimen. A mandrel of the desired diameter and a roller of diameter 2.5 mm make contact with the flesh and the grain surface respectively of the middle portion of the specimen, across its full width. The axis of both mandrel and roller are perpendicular to the length of the specimen: the axis of the mandrel is fixed relative to the clamp: the axle of the roller is attached to a handle-pivoted at the axis of the mandrel. Reading of load was recorded and Average was taken from the six readers to represent one sample and the test was repeated for other samples [8,19,20].

Chemical tests

Determination of moisture

According to [21-23] about 5 grams of the prepared sample were weighed in a suitable crucible, previously dried in oven and weighed. It is then dried to a constant weight at 100° - 105°C in the oven. The weight should be considered to be constant when two weights, at an interval of two hours, do not differ by more than 5 mg. The first weight should be made after an uninterrupted stay of the sample in the oven for 6 hours:

$$\text{Moisture \%} = \frac{\text{Weight before drying - Weight after drying} \times 100}{\text{Weight before drying}}$$

Determination of total ASH

According to [21,24] about 5 grams of the prepared sample were weighted in a porcelain crucible after being dried. Then burned to dull Bunsen red heat and cooled. The cold sample wetted with concentrated sulphuric acid and again burned, until all the carbon is consumed. Crucible with sample burned on the muffle furnace at 800°C is then cooled in a desiccator and weighed:

$$\text{Total ash \%} = \frac{\text{Weight of ash} \times 100}{\text{Dry weight of sample}}$$

Determination of fats and oils

According to [21,25] 20 grams of the prepared sample were weighed and replaced in a soxhlet extractor with a weighed flask. Oils and fats were then extracted with petroleum ether for 4 hours siphoning every ten minutes, until free from oils and fats. The solvent was distilled off completely and the residue was dried at 100 ° C in a suitable oven for about 5 hours till a constant weight was obtained.

$$\text{Fat and oil content \%} = \frac{\text{Residue weight} \times 100}{\text{Weight of sample}}$$

Residue weight = (Weight of flask with residue - empty flask weight).

Determination of chromium

The procedure according to [26-28] chromium was determined as follow:

1. From the ash prepared before, 3 - 4 times of it is weighed then taken and mixed with fusion mixture containing equal parts of sodium carbonate anhydrous, potassium carbonate and borax glass (anhydrous borax) in a porcelain crucible and fused for 30 minutes in a Bunsen flame till the fusion is transformed from tri-chromium salts to chromates with it is red-orange color.
2. The fusion is then cooled and diluted with 150 ml of hot distilled water.
3. The fusion is then filtrated from insolvent materials and completed to 250 ml. with distilled water.
4. From the filtrate solution 25 ml were taken in 300 ml conical flask, then 100 ml distilled water, 10 ml concentrated hydrochloric acid and 10 ml potassium iodide solution were added, respectively.

5. Then the conical flask is covered and stand 10 minutes preferably in the dark and titrated with 0.1N sodium thiosulphate till light yellowish color is obtained and then few drops of starch solution were added and when the titration is completed the blue color disappears.

6. Calculations: 1ml 0.1 N sodium thiosulphate equivalent to 0.00253 gram Cr_2O_3. Or 0.00173 gram Cr.

$$\text{Chrome oxide \%} = \frac{W_1 \times 0.00253 \times 100}{W_2}$$

Where:

W_1 = Volume of sodium thiosulphate used in titration.

W_2 = Weight of sample.

Statistical analysis

For whole variations Randomize Complete Block Design (RCBD) was used for data analysis according to [34]. One way ANOVA was done. LSD was used for means separation, besides comparing camel hides and leather measurements results with European, Indian and Sudanese Standard thresholds for shoe upper leather quality.

Results

Camel leather physical quality

Camel leather thickness at elongation test means values were 0.142 ± 6.68, 0.145 ± 2.64 and 0.157 ± 5.87 cm in summer, winter and autumn respectively. Significant differences ($P \leq 0.05$) were detected among camel leather thickness at elongation test. Where the highest value of the thickness at elongation test (0.157 ± 5.87 cm) was reported in autumn season and statistically differs from the values of summer and winter seasons (Table 1).

Sample	Summer	Winter	Autumn
1	0.145	0.148	0.150
2	0.145	0.149	0.153
3	0.145	0.146	0.152
4	0.133	0.147	0.160
5	0.138	0.145	0.160
6	0.150	0.145	0.162
7	0.150	0.145	0.165
8	0.144	0.143	0.165
9	0.144	0.143	0.152
10	0.130	0.140	0.152
Mean	0.142 ± 6.68^b	0.145 ± 2.64^b	0.157 ± 5.87^a
Sudanese, Indian, Europe Standards		0.150 cm	

Table 1: *Camel leather thickness at elongation test.*

Means with the same superscripts not significantly differ at 0.05.

Also, significant differences ($P \leq 0.05$) were observed among elongation percentages values of camel leather by the year seasons differ. The highest value of elongation % of 43.73 ± 2.21 was reported in summer season. The lowest value of elongation (26.60 ± 7.8%) was recorded in autumn season which was not significantly differing from the percentage value of winter season of 31.22 ± 10.45 (Table 2).

Sample	Summer	Winter	Autumn
1	44.4	25.5	25.0
2	41.4	25.3	25.0
3	41.4	29.0	25.0
4	40.5	27.0	23.0
5	43.1	22.0	23.0
6	45.0	22.5	23.0
7	44.0	22.9	20.0
8	44.5	46.0	20.0
9	45.0	44.0	41.0
10	48.0	48.0	41.0
Mean	43.73 ± 2.21^{a}	31.22 ± 10.45^{b}	26.60 ± 7.8^{b}
Sudanese’s Indian, Europe Standards		45%	

Table 2: *Camel leather elongation percentage.*

Means with the same superscripts not significantly differ at 0.05.

Statistical analysis shows significant differences ($P \leq 0.05$) between year season’s mean values of camel leather tensile strength. The highest mean value of 219 ± 3.56 Kg/cm^2 was obtained in autumn season. The lowest value of tensile strength (195 ± 6.55 Kg/cm^2) was reported in summer season (Table 3).

Sample	Summer	Winter	Autumn
1	202	211	218
2	202	210	218
3	202	208	215
4	198	209	218
5	195	215	221
6	194	214	215
7	194	214	221
8	194	204	221
9	193	205	225
10	180	198	225
Mean	195 ± 6.55^{c}	208 ± 5.30^{b}	219 ± 3.56^{a}
Sudaneses Indian, Europe Standards		200 kg/cm^2	

Table 3: *Camel leather tensile strength kg/cm^2.*

Means with the same superscripts not significantly differ at 0.05.

Camel leather resistance to grain cracking results showed significant differences ($P \leq 0.05$) among the year seasons. The highest mean value of 6.84 ± 0.28 was reported in autumn season and it was not significantly differs from the mean value of winter season (6.74 ± 0.28 Kg/cm^2). While the lowest mean value of 5.46 ± 0.20 kg/cm^2 was recorded in summer season (Table 4).

Sample	Summer	Winter	Autumn
1	5.7	6.8	6.7
2	5.7	6.8	6.7
3	5.7	6.6	6.7
4	5.5	6.6	6.9
5	5.5	7.1	6.9
6	5.4	7.1	6.9
7	5.4	7.1	7.3
8	5.3	6.5	7.3
9	5.3	6.5	6.5
10	5.1	6.3	6.5
Mean	5.46 ± 0.20^b	6.84 ± 0.28^a	6.74 ± 0.28^a
Sudaneses Indian, Europe Standards		7.0 kg/cm^2	

Table 4: *Camel leather resistance to grain cracking.*

Means with the same superscripts not significantly differ at 0.05.

Camel leather breaking load results showed significant differences ($P \leq 0.05$) among the year seasons. The highest mean value of 8.03 ± 0.350 Kg/cm^2 was reported in autumn season and it was not significantly differs from the mean value of winter season of 7.84 ± 0.42 Kg/cm^2. While the lowest mean value of 6.84 ± 0.55 kg/cm^2 was recorded in summer season (Table 5).

Sample	Summer	Winter	Autumn
1	7.5	8.0	7.9
2	7.5	8.0	7.9
3	7.5	7.8	7.9
4	7.1	7.8	8.2
5	7.1	8.3	8.2
6	6.5	8.3	8.2
7	6.5	8.3	8.5
8	6.3	7.4	8.5
9	6.3	7.4	7.5
10	6.1	7.1	7.5
Mean	6.84 ± 0.55^b	7.84 ± 0.42^a	8.03 ± 0.35^a
Sudaneses Indian, Europe Standards		8.0kg/cm^2	

Table 5: *Camel leather breaking load.*

Means with the same superscripts not significantly differ at 0.05.

Camel leather thickness at double holes tear strength results revealed that there were significant differences ($P \leq 0.05$) were detected among the seasonal recorded values. The highest thickness mean value at double holes tear strength test was 0.160 ± 7.23 cm and recorded at autumn season. While the lowest value of 0.137 ± 4.0 cm was recorded in summer season (Table 6).

Sample	Summer	Winter	Autumn
1	0.142	0.147	0.155
2	0.142	0.147	0.155
3	0.142	0.143	0.155
4	0.140	0.143	0.166
5	0.140	0.167	0.166
6	0.135	0.167	0.166
7	0.136	0.167	0.169
8	0.133	0.143	0.169
9	0.133	0.143	0.152
10	0.130	0.141	0.152
Mean	0.137 ± 4.0^{c}	0.150 ± 6.0^{b}	0.160 ± 7.23^{a}
Sudaneses Indian, Europe Standards		0.150cm	

***Table 6**: Camel leather thickness at double hole tear strength test.*

Means with the same superscripts not significantly differ at 0.05.

Double holes tear strength results showed significant differences ($P \leq 0.05$) among tested samples of camel leather. The highest mean value of 176.80 ± 6.17 Kg/cm^2 was reported in autumn season. While the lowest value of 137.70 ± 9.94 kg/cm^2 was reported for camel leather sample in winter. But in summer the mean value of 155.30 ± 15.59 kg/cm^2 was reported for camel leather that tested for the Double holes tear strength (Table 7).

Sample	Summer	Winter	Autumn
1	150	160	174
2	150	160	174
3	150	145	174
4	141	145	180
5	141	175	180
6	132	175	180
7	132	175	185
8	128	140	185
9	128	140	168
10	125	138	168
Mean	137.70 ± 9.94^{c}	5.30 ± 15.59^{b}	76.80 ± 6.17^{a}
Sudaneses Indian, Europe Standards		80 kg/cm^2	

***Table 7:** Camel leather double holes tear strength.*

Means with the same superscripts not significantly differ at 0.05.

Autumn mean values of thickness at tear strength test (0.153 ± 5.25 cm) was statistically differ ($P \leq 0.05$) from the mean values that reported for camel leather at winter and summer seasons of 0.149 ± 2.71 and 0.148 ± 3.22 respectively (Table 8).

Sample	Summer	Winter	Autumn
1	0.152	0.150	0.155
2	0.152	0.150	0.153
3	0.151	0.148	0.153
4	0.150	0.148	0.156
5	0.150	0.153	0.157
6	0.147	0.153	0.156
7	0.147	0.153	0.158
8	0.145	0.147	0.158
9	0.145	0.147	0.144
10	0.143	0.146	0.144
Mean	0.148 ± 3.22^{b}	0.149 ± 2.71^{b}	0.153 ± 5.25^{a}
Sudaneses Indian, Europe Standards		0.150 cm	

Table 8: *Camel leather thickness at tear strength test.*

Means with the same superscripts not significantly differ at 0.05.

Camel leather tear strength means values were 89.54 ± 7.14, 90.92 ± 6.49 and 93.56 ± 5.27 Kg/cm^2 in summer, winter and autumn respectively. No significant differences ($P \leq 0.05$) were detected among camel leather tear strength test mean values (Table 9).

Sample	Summer	Winter	Autumn
1	98.0	93.2	90.0
2	98.0	93.5	90.0
3	98.0	88.5	90.0
4	92.5	88.5	95.2
5	92.5	98.6	95.2
6	86.2	98.5	95.2
7	86.2	98.6	102.0
8	82.0	84.3	102.0
9	82.0	84.0	88.0
10	80.0	81.5	88.0
Mean	89.54 ± 7.14^{a}	90.92 ± 6.49^{a}	93.56 ± 5.27^{a}
Sudaneses, Indian & Europe Stands		100 kg/cm^2	

Table 9: *Camel leather tear strength.*

Means with the same superscripts not significantly differ at 0.05.

Camel leather thickness at flexibility test mean values were significantly differ ($P \leq 0.05$) among the year seasons. The highest value of 0.152 ± 2.86 cm was reported in autumn season. While the means values of winter and summer season were 0.148 ± 3.62 and 0.145 ± 1.90 cm respectively (Table 10).

Sample	Summer	Winter	Autumn
1	0.148	0.150	0.152
2	0.147	0.150	0.152
3	0.148	0.147	0.152
4	0.146	0.146	0.154
5	0.146	0.153	0.155
6	0.145	0.153	0.155
7	0.145	0.153	0.156
8	0.144	0.145	0.155
9	0.144	0.145	0.148
10	0.142	0.144	0.148
Mean	0.145 ± 1.90^{c}	0.148 ± 3.62^{b}	0.152 ± 2.86^{a}
Sudaneses Indian, Europe Standards		0.150 cm	

Table 10: *Camel leather thickness at flexibility test.*

Means with the same superscripts not significantly differ at 0.05.

Camel leather flexibility percentages values were significantly different ($P \leq 0.05$) by the year seasons differ. The better flexibility percentage was recorded in winter season of 62.30 ± 2.75. Meanwhile no significant difference was detected between autumn and summer seasons of 57.20 ± 3.93 and 57.20 ± 3.93 respectively (Table 11).

Sample	Summer	Winter	Autumn
1	54	61	60
2	53	61	60
3	53	63	59
4	55	63	57
5	55	59	58
6	58	59	56
7	58	60	55
8	60	65	55
9	61	65	62
10	65	67	62
Mean	57.20 ± 3.93^{b}	62.30 ± 2.75^{a}	58.40 ± 2.63^{b}
Sudaneses Indian, Europe Standards		100%	

Table 11: *Camel leather flexibility.*

Means with the same superscripts not significantly differ at 0.05.

Camel leather chemical quality

Significant differences ($P \leq 0.05$) were detected among camel leather moisture percentages values by the year season differ. The highest percentage of 4.75 ± 0.16 and 4.66 ± 0.24 were determined in winter and autumn season respectively. While the lowest percentage value of 4.40 ± 0.23 was determined in summer season (Table 12).

Sample	Summer	Winter	Autumn
1	4.7	4.8	4.73
2	4.7	4.79	4.73
3	4.6	4.70	4.73
4	4.5	4.70	4.69
5	4.5	4.96	4.69
6	4.3	4.95	4.70
7	4.3	4.95	4.88
8	4.2	4.6	4.89
9	4.2	4.59	4.60
10	4.0	4.50	4 .50
Mean	4.40 ± 0.23^{b}	4.75 ± 0.16^{a}	4.66 ± 0.24^{a}
Sudaneses Indian, Europe Standards		18%	

Table 12: *Camel leather moisture content percentage.*

Means with the same superscripts not significantly differ at 0.05.

Also, significant differences ($P \leq 0.05$) were detected among camel leather Ash percentages values by the year season differ. The highest percentage of 6.27 ± 0.28 and 6.34 ± 0.20 were determined in winter and autumn season respectively. While the lowest percentage value of 6.00 ± 0.30 was determined in summer season (Table 13).

Sample	Summer	Winter	Autumn
1	6.20	6.30	6.29
2	6.20	6.30	6.29
3	6.20	6.28	6.29
4	6.30	6.28	6.34
5	6.30	6.62	6.34
6	6.10	6.60	6.34
7	5.90	6.60	6.70
8	5.80	6.00	6.70
9	5.50	6.00	6.10
10	5.50	5.80	6.10
Mean	6.00 ± 0.30^{b}	6.27 ± 0.28^{a}	6.34 ± 0.20^{a}
Sudaneses Indian, Europe Standards		4.5%	

Table 13: *Camel leather ash content percentage.*

Means with the same superscripts not significantly differ at 0.05.

No significant differences ($P \leq 0.05$) were detected among camel leather fat content percentages values by the year season differ. Fat content percentage of 9.58 ± 0.47, 9.38 ± 0.31 and 9.40 ± 0.35 were determined in summer, winter and autumn season respectively (Table 14).

Sample	Summer	Winter	Autumn
1	9.7	9.4	9.3
2	9.7	9.4	9.3
3	9.7	9.2	9.3
4	9.9	9.2	9.82
5	9.4	9.8	9.83
6	9.4	9.8	9.83
7	9.3	9.8	10.3
8	9.1	9.1	10.2
9	9.0	9.1	9.0
10	8.8	9.0	9.0
Mean	9.40 ± 0.35^a	9.38 ± 0.31^a	9.58 ± 0.47^a
Sudaneses Indian, Europe Standards		11%	

Table 14: *Camel leather fat content percentage.*

Means with the same superscripts not significantly differ at 0.05.

Significant differences ($P \leq 0.05$) were detected among camel leather chrome oxide content percentages values by the year season differ. Chrome oxide content highest percentage of 3.53 ± 0.25 and 3.23 ± 0.14 were determined in winter and autumn season respectively. While the lowest percentage value of 3.08 ± 0.25 was determined in summer season (Table 15).

Sample	Summer	Winter	Autumn
1	3.2	3.7	3.2
2	3.2	3.7	3.2
3	3.2	3.4	3.2
4	3.5	3.4	3.3
5	3.1	3.8	3.3
6	3.1	3.8	3.3
7	3.0	3.8	3.4
8	3.0	3.3	3.4
9	3.0	3.3	3.0
10	2.5	3.1	3.0
Mean in mm.	3.08 ± 0.25^b	3.53 ± 0.25^a	3.23 ± 0.14^b
Sudaneses Indian, Europe Standards		2.5%	

Table 15: *Camel leather chrome oxide content percentage.*

Means with the same superscripts not significantly differ at 0.05.

Discussion

Camel leather physical quality

Physical tests always give an idea about future live of tanned leathers when used in articles manufacturing purposes. Flexibility, elasticity and tensile strength are the most common tests needed to determine leathers viability especially in manufacturing leather goods [29].

In this study thickness at elongation test values of 0.142 ± 6.68, 0.145 ± 2.64 cm were reported in summer and winter respectively, which were below the minimum threshold for Sudanese, Indian and Europe standards specification for cattle leather thickness of 0.150 cm. But the thickness at elongation test value for camel tanned leather in autumn (0.157 ± 5.87cm) was above the minimum threshold for Sudanese, Indian and Europe standards specification for cattle leather thickness. Generally, the thicker hides or skins are desirable quality for leather articles manufacturing as it mentioned by (Elliot, 1981) who stated that, the thinner skins which contain looser and emptier fiber texture are termed skins of poor substance. These results confirm [30] who stated that, the average thickness in camel's leathers ranged between 0.121 - 0.165 cm.

More Elastic leathers are considered one of the undesirable qualities, especially in shoes and leather belts manufacturing. When elasticity is more than necessary, the produced shoes not takes a fixed or sagging form and leather belts is not tight and expands. But elastic leather used in manufacturing of garment leather such as suede's leather [29]. The results of experienced camel leather indicated that elongation percentages were 26.60 ± 7.8, 31.22 ± 10.45 and 43.73 ± 2.21 which were recorded in autumn, winter and summer season respectively. These percentage values of camel leather elongation were below the minimum threshold for Sudanese, Indian and Europe standards specification for cattle leather elongation of 45%. These results are confirm [30,31] whom estimated the average elongation for camel leather ranged between 21 - 45%, which was less than the average elongation in cattle's leathers

Strength and stout are one of the most important leather quality characters which give an indicator for leather expected life specially when manufactured as leather articles. In this study the lowest value of tensile strength (195 ± 6.55 kg/cm^2) was reported in summer season which is below the minimum threshold for Sudanese, Indian and Europe standards specification for cattle leather tensile strength of 200 kg/cm^2. While the means values of autumn and winter seasons (219 ± 3.56 and 208 ± 5.30 Kg/cm^2) were above the Sudanese, Indian and Europe standards specification for cattle leather tensile strength. These results are in line with [30] who found that the average tensile strength in Camel's leathers ranged between 185 - 245 Kg/cm^2, which is approximately equal to tensile strength of cattle's leathers tensile strength. But they were not in Nasr [31] range for camel tensile strength that between 215 - 241 Kg/cm^2.

Camel leather resistance to grain cracking results of 5.46 ± 0.20, 6.74 ± 0.28 and 6.84 ± 0.28 Kg/cm^2 were below the minimum threshold for Sudanese, Indian and Europe standards specification for cattle leather resistance to grain cracking load of 7.0 Kg/cm^2. But it in confirm with [30] who reported that, the average tear load at the grain cracking was ranged between 5.4-8.2 Kg/cm^2, which were greater than that found in cattle's leathers.

Camel leather breaking load mean value of 8.03 ± 0.350, 7.84 ± 0.42 and 6.84 ± 0.55 Kg/cm^2 were reported in autumn, winter and summer season respectively. Camel leather breaking load results in winter and summer season were below the minimum threshold for Sudanese, Indian and Europe standards specification for cattle leather breaking load of 8.0 Kg/cm^2. While autumn result was in the minimum threshold for Sudanese, Indian and Europe standards specification for cattle leather breaking load.

Tear strength at double holes is one of the quality character needed in manufacturing of leather goods or articles. The high values of this character allow to joint two pieces of leather together by sawing needle where the holes are more resistance to puncturing. This character is needed in garments, shoes and other leather articles manufacturing. The result indicated that, autumn and winter seasons mean values for thickness at double holes tear strength test of 0.160 ± 7.23 and 0.150 ± 6.0 cm respectively were above and in the minimum threshold for Sudanese, Indian and Europe standards specification for cattle leather thickness at double holes tear strength test of 0.150 cm. The lowest value of thickness at double holes tear strength test of 0.137 ± 4.0 cm was recorded in summer season and it was below the minimum threshold of Sudanese, Indian and Europe standards specification for cattle leather thickness at double holes tear strength test. But these results in confirm with [30] who reported that, the average thickness in double hole rupture strength test was between 0.125 - 0.152 cm.

Camel leather double holes tear strength highest mean values of 176.80 ± 6.17, 155.30 ± 15.59 and 137.70 ± 9.94 kg/cm^2 were reported in autumn, winter and summer season respectively. These means were above the minimum threshold of Sudanese, Indian and Europe standards specification for cattle leather double holes tear strength of 80kg/cm^2. Also, it confirm [30] who mentioned that, the average tear strength of the double hole rupture ranged between 130 - 180 Kg/cm^2 which was less or equal to the strength of the hole tearing strength in cattle's leathers.

Camel thickness at tear strength autumn mean value of 0.153 ± 5.25 cm was above the minimum threshold of Sudanese, Indian and Europe standards specification for cattle leather thickness at tear strength test. While the mean values of 0.149 ± 2.71cm and 0.148 ± 3.22 cm which recorded in winter and summer seasons respectively, were below the minimum threshold of Sudanese, Indian and Europe standards specification for cattle leather thickness at tear strength test of 0.150 cm.

Camel leather tear strength means values were 89.54 ± 7.14, 90.92 ± 6.49 and 93.56 ± 5.27 Kg/cm^2 in summer, winter and autumn respectively. These mean values were below the minimum threshold of Sudanese, Indian and Europe standards specification for cattle leather tear strength test of 100 kg/cm^2.

Camel leather thickness at flexibility test highest value of 0.152 ± 2.86 cm was reported in autumn season and it in the minimum threshold of Sudanese, Indian and Europe standards specification for cattle leather thickness at flexibility test of 0.150 cm. While the means values of winter and summer season of 0.148 ± 3.62 and 0.145 ± 1.90 cm respectively, were below the minimum threshold of Sudanese, Indian and Europe standards specification for cattle leather thickness at flexibility test.

Leather Flexibility is one of the specifications required for leather manufacturing. So, the more flexible leather can be formed into multiple and wide variety of leather products. In shoes manufacturing, leather flexibility measured the life time of the shoe, it is ability to take the shape of the foot and the possibility of bending when moving with the shoe [29].

In this study the flexibility percentages of 62.30 ± 2.75, 58.40 ± 2.63 and 57.20 ± 3.93 were recorded in winter, autumn and summer season respectively, which were below the minimum threshold of Sudanese, Indian and Europe standards specification for cattle leather flexibility test of 100%. Also, it disagrees with [30] who found that the average flexibility (hide flexion) in camel's leathers was ranged between 65 - 75%.

Camel leather chemical quality

Camel leather Ash contents% of 6.27 ± 0.28 and 6.34 ± 0.20, 6.00 ± 0.30 were determined in winter, autumn and summer season respectively. These percentages values were above the minimum threshold of Sudanese, Indian and Europe standards specification for cattle leather Ash content of 4.5%. These values of Ash contents are confirm [30] results who stated that, the average percentage of ash in camel leathers were between 6.6 - 6.5%, which is much greater than that found in cattle hides; this is due to the absorption of high percentages of chromium oxide. Also, these results were above [31] who mentioned that, the average percentage of ash in Egyptian camel leathers were between 4.14 - 4.40%.

Camel leather fat content percentages of 6.27 ± 0.28, 6.34 ± 0.20 and 6.00 ± 0.30 were determined in winter, autumn and summer season respectively. These percentages values were below the maximum threshold of Sudanese, Indian and Europe standards specification for cattle leather fat content of 11%. But they in [31] estimated range of 5.77-9.28% for Egyptian camel leather fat contents.

The quality and efficiency of tanning is assessed by the extent penetration of the tanning material such as chrome oxide into skins or hide fibres. Also, it gives the hide the ability to resist all natural conditions of moisture, heat, etc. Tanned leather becomes a stable material that is not subject to putrefaction and has a longer life than raw un-tanned leather. The efficient tanning enables tanned leather to resist bacterial putrefaction.

Chrome oxide content highest percentages of 3.53 ± 0.25, 3.23 ± 0.14 and 3.08 ± 0.25 were determined in winter autumn and summer season respectively. These percentages values were above the minimum threshold of Sudanese, Indian and Europe standards specification for cattle leather chrome oxide content of 2.5%. These results are in confirm with [30-32] whom mentioned that, the average percentage of chromium oxide in camel's leather is between 2.9 - 4.3% and which was much greater than what was found in cattle's hides, due to the opening pores of camel's hides and their natural preparation to absorb substances.

Moisture content percentages of 4.75 ± 0.16, 4.66 ± 0.24 and 4.40 ± 0.23 were determined in winter autumn and summer season respectively. These percentages values were below the maximum threshold of Sudanese, Indian and Europe standards specification for cattle leather moisture content. But they are in line with [30] who found that the average moisture content in camel leathers ranged between 4.2 - 4.95%, which is lower than that found in cattle hides. But [31] found that moisture contents in Egyptian camel leather were between 14 - 14.21%.

Conclusion

The study concluded that, season of the year were affect on most camel leather properties. Fat content and tear strength were not affected by the season. Camel leather is similar in it is quality to cattle leather, but less in tear strength, double holes tear strength and flexibility properties. Though, camel leather is suitable for manufacturing all types' of cattle leather articles such as foot wear, bags, saddles, belts. So, camel hides can serve as important source of income to pastoralists if there is a reliable market and if they are properly produced, cured and tanned.

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