Sudan university of sciences and technology

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A study on Production and Quality of Camel Hides in Khartoum state

دراسة عن أنتاج وجودة جلود الإبل في ولاية الخرطوم

A thesis submitted in fulfillment of the Requirements for the Degree of Master of Science in animal production

By

Manahil Hassan Ahmed Babiker

B.Sc. (Honours) Animal Production

Sudan University of Science and Technology (2004)

Major Supervisor**: Prof. Ali Elnaeim Musa**

Department of leather Technology - college of Applied and Industrial Sciences - University of Bahri

Co- Supervisor **: Dr. Ebtesam Ali Hassan Ali**

Department of meat sciences, college of animal production science and technology

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DEDICATION

This work is dedicated to all of my family and friends

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I wish to express my deep sense of gratitude to my research supervisors **Prof. Ali Elnaeim Musa,** University of Bahri, College of Applied and Industrial Sciences, Department of Leather Technology and **Dr. Ebtesam Ali Hassan**, Assistant Professor, College of Animal Production Sciences and Technology, University of Sudan of Sciences and Technology**, my thanks extended to white nile tannery and National Leather Technologies Centre (NLTC)**, for their valuable guidance and encouragement during this work.

Table Of Contents

List of Tables

List of Figures

ABSTRACT

Sudan is one of the African countries with higher livestock population. The total livestock population of the country is estimated at 31.78 millions of cattle, 41 millions of sheep, 32.22 millions of goats and 4.92 millions of camels. This huge population of livestock provides many opportunities for the development of the leather sector in the country. The main source of raw material for the Sudan tanning sector comes from sheep, goat and cattle. Camel (*Camelus dromedarius*) is one of the most important livestock uniquely adapted to hot dry environments. Sudan holds the second largest camel population in the world (about 4.92 million). Camels in Sudan and elsewhere are classified as pack (heavy) and riding (light) types according to their function. Recent studies have been made to classify the camels according to their performance (dairy camels, meat camels, dual purpose camels and racing camels). In the present study, camel hides were used for manufacture of upper crust leathers and compare with conventional cow hides. Histological analysis of the camel hide and cow hide has been carried out at soaking operation. The physical and chemical analysis indicates that the experimental camel leathers are comparable to control cow leathers in terms of all the properties. The bulk properties (softness , fullness, grain tightness and appearance) for the experimental leathers are better than control leathers. Scanning electron microscopic analysis for both control and experimental leather samples show good separation of fiber bundles. The chemical and physical characteristics of the experimental camel leather revealed that the camel hide raw material was suitable for making of shoe upper leather. In Sudan camel was considered as best alternative animal to conventional raw materials such as sheep, goat and cattle due to its higher off take rate.

ملخص البحث

السودان احدي الدول الافريقية التي تمتلك ثروة حيوانية كبير – و تقدر الثروة الحيوانية بعدد 31,78 مليون راس من الابقار, 41 مليون من الضأن , 32,22 مليوم من الماعز و 4,92 مليون من الابل. هذا العدد الضخم من الثروة الحيوانية يفتح فرص كثيرة لتطوير قطاع الجلوم في البلاد. المصدر الرئيسي للجلود الخام لقطاع الدباغة في السودان يأتي من الابقار , الضأن و الماعز. تعتبر الجمال وحيدة السنام من اهم الماشية التي تكيفت علي البيئات الحارة الجافة استثنائيا. السودان يعتبر ثاني اكبر دولة عالميا تمتلك اعداد من الابل تقدر بحوالي 4,92 مليون راس من الابل.تصنف الابل في السودان و المناطق الاخري طبقا لوظائفها الي ابل حمل (ثقيلة) و ابل ركوب (خفيفة). الدراسات الحديثة صنفت الابل طبقا لادائها الي ابل لبن , ابل لحم , ابل ثنائية الغرض و ابل سباق. في الدراسة الحالية جلود الابل استعملت لصناعة لصناعة جلود كرست لوجه الحذاء وتم مقارنتها مع جلود الابقار التقليدية. تم اجراء التحليل الهستولوجي لجلود الابل و جلود الابقار في مرحلة البلل. التحليل الفيزيائي و الكيميائي للجلود يوضح ان جلود الابل للتجارب مقارنة في كل المميزات مع جلود الابقار للتحكيم. التحليل بواسطة المجهر الالكتروني لعينات جلود التجارب و جلود التحكيم أوضحت الانفصال الجيد للحزم الليفية. الخواص الكيميائية و الفيزيائية لجلود التجارب (الابل) اوضحت ان جلود الابل الخام مناسبة لصناعة جلود وجه الحذاء. في السودان يعتبر الجمل افضل حيوان بديل للحيوانات التقليدية المستخدمة في صناعة الجلود مثل الضأن , الماعز و الابقار وذلك بسبب معدل المسحوب العالي للابل.

Chapter One

Introduction

Camel in Sudan

The camel is an important species uniquely adapted to hot and arid environments (Schwartz, 1992). The camels of Sudan belong to the species *Camelus dromedarius*, and are owned and raised by nomadic tribes. Camel herders migrate north in the wet season and south during the dry season. Camels in the Sudan are classified as pack (heavy) and riding (light) types according to the function they perform. These traits were probably developed as a result of selection applied by the various camel owning tribes. The Sudanese heavy type camels constitute the majority of the camels kept by nomads in Sudan. Within this group two subtypes can be identified on the basis of conformation and tribal ownership: The Arab (Figure 1.1) and Rashaidi (Figure 1.2) camels. The Arab camel may be further subdivided into Light Pack, Big Arabi and Heavy Arabi. On the other hand, the riding camels are restricted to the north-east of the country between the Nile and Red Sea. The two main recognized riding types are Anafi (Figure 1.3) and Red Sea Hills (Bishari) (Figure 1.4) camels (El-Fadil 1986). Middle East camel hide is used for manufacturing utility items for tourists (Bakhat and Sahani, 2000).

Sudan is one of the largest camel populated countries in the world. Its population is about 3.2 millions (FAO, 2002). Sudan and Somalia have 70% of the total African camels and 55% of that of the world camel's population (Wilson 1984). The camels were, and still are, valued as riding, baggage, draught animals, hair hides and as well as the best food providers in the arid areas (Sweet, 1965). In Sudan, camel breeds are classified into pack and riding camels (Babiker, 2000).

Tanning is generally carried out by effective crosslinking or stabilising the animal hide collagen, using tanning agents known as tannins. Although there are various types of vegetable, synthetic, organic and mineral tannins, chrome tanning is still the most common mineral tanning agent used to convert hides and skins into leather. Approximately 90% of the leather produced globally is chrome-tanned. Chrome-tanned leather shows high shrinkage temperature or high hydrothermal stability, good flexibility, excellent fastness properties, lightweight with good comfort characteristics, good moulding and shape retention properties (Dasgupta, 2004).

According to the World Food Organization (FAO), there were 24,644,228 camels in the world 85% of which have been living in Africa (equal to 20,969,015 camels) (Taghi, 2017). Sudan ranks first among the Arab countries and second in Africa with respect to animal population. The Sudan is considered as the second country in the world in camel's population (more than **4** millions). The history of the dromedary camel in the Sudan is even more obscure. Camels in the Sudan are spread in a belt configuration; it extends between latitudes 12°-16°N. This belt is characterized by errati**c** rainfall, **less** than 350 mm. and contains two main regions: the Eastern state, whereas camels are found in the Butana plains and the Red Sea hills and the Western Regions (Darfour and Kordofan). In Sudan the production systems include: traditional nomadic system, transhumant or semi-nomadic system, sedentary or semi-sedentary system and intensive system which is limited to racing and dairy camels (Eisa and Mustafa 2011).

Problem statement

Sudan has the richest livestock population in Africa, i.e. cattle, sheep and camels. Sudan has largest population of camels among Arab countries and the tanning sectors depend only on sheep, goats and cattle for making of different leather products.

This research work aims to finding an additional raw material resource for leather making. Camel hides are being considered as an additional source to the leather industries. Also the aims of this study to evaluate the camel hide and compare with cow hide that used mainly in Sudanese tanneries.

Objectives of this study

General objectives

The general objective of this study is to evaluate Sudanese camel hides and use these raw materials as an additional resource for leather making and compare with cow hides.

Specific objectives

- To evaluate the characteristics of the camel hide and leather according to , histological studies , physical analysis , chemical analysis and scanning electro-microscopic analysis .
- To compare the characteristics of quality camel leather (experimental) with that of cow leather (control) .

Chapter Two
Literature Review

2.1. Sudanese Livestock and Camels

Sudan has the richest livestock population in Africa, i.e. cattle, sheep, goats and camels. Sudan has largest population of camels among Arab and African countries and the tanning sectors depend only on sheep, goats and cattle for making of different leather products. Camels are classified as under: Class: mammals, Order: Artiodactyla, Sub-Order: Tylopoda and Family: Camiladae (Table 2.1) (Simpson 1964). There are two genera in this family including Camelus genus (camels in ancient world) and lama genus (camels in the new world, camels without hump). The Camelus genus includes two species: *Camelus dromedarius* (dromedary) and Bactrian camels (*Camelus bactrianus*) (Al-Swailem *et al*,. 2007).

Table 2.1 The Taxonomy of Camel (Simpson, 1964).

Kingdom	Animalia
Subkingdom	Metazoa
Phylum	Chordata
Subphylum	Vertebrata
Superclass	Tetrapoda
Class	Mammalia
Subclass	Theria
Infraclass	Eutheria
Cohort	Ferungulata
Superorder	Paraxonia
Order	artiodactyla

Suborder	Tylopoda
Family	Camelidae
Subfamily	Camelinae
Genus	Camelus
Species	*Dromedariusm bactrianus*

Camels in the Sudan and elsewhere are classified as pack (heavy) and riding (light) types according to the function they perform and probably as a result of the selection applied for this trait by the various camel keeping tribes .The Sudanese heavy type constitutes the majority of the camels kept by nomads in Sudan. Two types of camels can be identified on the basis of body conformation and tribal ownership: the Arab and Rashidi Camels. On the other hand, the riding camels are restricted to the north-east of the country between the River Nile and Red Sea**.** For Sudanese riding camels there are two main types, namely Anafi and Bishari Camels (Ishag, 2009).

Animals are generally slaughtered at old ages with a decline in meat quality. Mean slaughter weight of fattened mature desert camels was 456 kg and mean empty body weight (EBW) was 404·8 kg (Yousif and Babiker 1989). Camels dressing percentages vary greatly and are affected by many factors. They vary from 47 to 62 and are affected by sex, age, breed or type, body condition and digestive tract contents (Kadim et al 2008). Fattened mature Sudanese desert camels dressing percentages were 55·8% on live body weight and 63·6% on EBW (Yousif and Babiker 1989) while Wilson (1978) reported a dressing percentage range of 47.4-51.4% for Sudanese desert camels. The empty body weight (EBW) was calculated by difference between animals live body weight and gut contents weight. Body components were calculated as percentages of EBW. Dressing percentage was calculated on LBW and EBW.

Camel hides are being considered as an additional source of raw material for the tanning industries (Belay *et al.*, 2019). Although camel leathers are characterized with higher strengths than cow leathers , there is still a lack in regarding evaluation of camel leather properties following tanning and finishing by different methods to use it in manufacturing (Ibrahim 2013).

Middle East camel hide used for manufacturing utility items for tourist (Bhakat & Sahani 2000,). Presently, camel hide appears to have little commercial use but if processed properly can be used for making leather goods, viz. shoes, sandals, etc. (Khanna, 2000). In order to add water-repellent properties to the finished leather, it is subjected to lacquer finishing also (Bhakat & Sahani, 2003).

Camel hides can be used for making fancy items of tourist interest and it needs to be explored because very few people bother to take out the skin of a dead camel whereas this is not the case with other livestock species. Wilson (1988) reported that the wet hides weighed between 22.5 and 47.0 kg, equivalent to between 8.5 and 11.8 percent of empty live-weight.

The histological structure of the skin of the camel, is basically similar to those of other domestic animals (Lee and Schmidt–Nielsen, 1962) except in the arrangement of hair follicles (Gbolagunte, 1983; Gbolagunte and Jamdar, 1984; Hekal, 2014). This similarity mainly concerns the general morphology; but the basic variation in characters, like the specific nature of the grain (area immediately below the epidermis) surface, in relation to the corium (lower dermis); the types of fibers found within the various layers and positions, and in the nature of weave of the fibers therein; all of which can influence the properties of the resultant leathers, have not been effectively established.

2.2. Structure of Skin

The structure of skin is divided into three distinct layers (Figure 1.5), the grain (epidermis) layer, the corium or dermis and the flesh (hypodermis) layers (Daniels, 2003). The grain layer of the skin gives the aesthetic value (Leafe, 1999) and determines the final appearance of the leather (Bailey and Paul, 1998). The outermost layer of the grain layer is epidermis, which is removed during the pre-tanning process (Daniels, 2003).

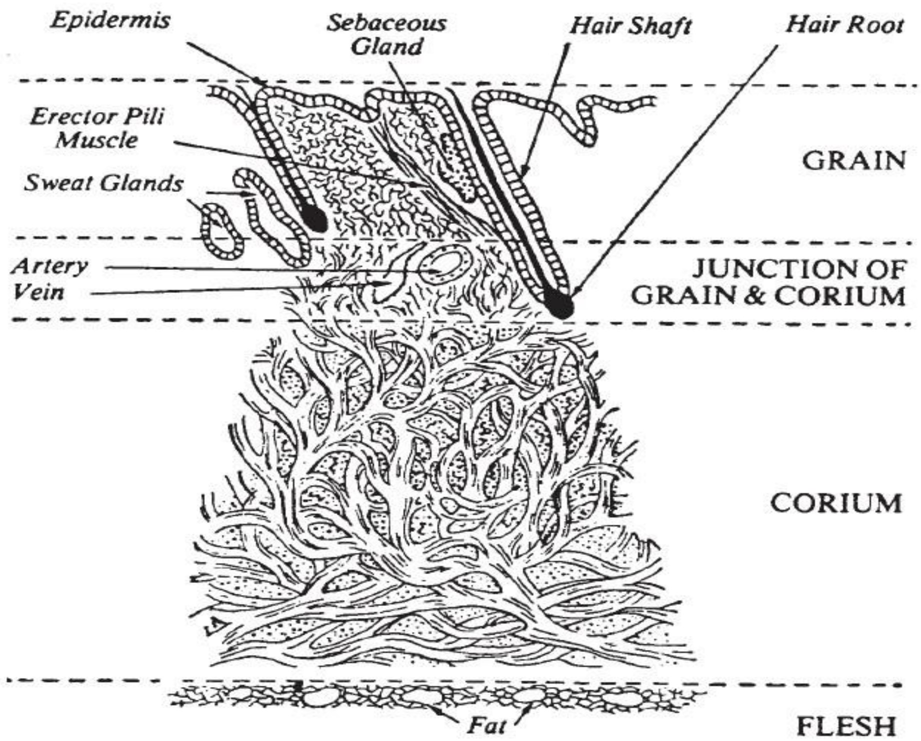


Figure 2.1 Structure of Skin of hide

The corium is relatively thick (Daniels, 2003) and composed of white interlacing collagen fibres cemented together by a substance called dermatan sulfate, in a net-like structure. The corium is responsible for the mechanical strength and resiliency (Leafe, 1999). Collagen type I is one of the major collagen types in animal bodies. Due to the formation of internal cross-links within the fine fibrils, the collagen is highly stable (Daniels, 2003).

The flesh layer composed of subcutaneous tissue mainly consists of adipose tissues. The flesh layer is also removed during the beamhouse processes.

Hides and skins, raw materials for the tanning industry, are renewable and easily perishable resources (Arugna, 1995). 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).

2.3. Leather-Tanning

Tanning is essentially the reaction of collagen fibers in the hide with tannins, chromium, alum, or other chemical agents. The most common tanning agents used is trivalent chromium and vegetable tannins extracted from specific tree barks. Alum, syntans, formaldehyde, glutaraldehye, and heavy oils are other tanning agents. (Bienkiewicz, 1983).

The tanning process is based on the conversion of putrescible skin or hides to a non-putrescible material. Leather making involves operations like soaking (rehydration), liming, deliming, pickling, tanning, posttanning and finishing processes. (Kanth et al. 2009) Figure 1.6 (Suresh, *et al.*,2001).

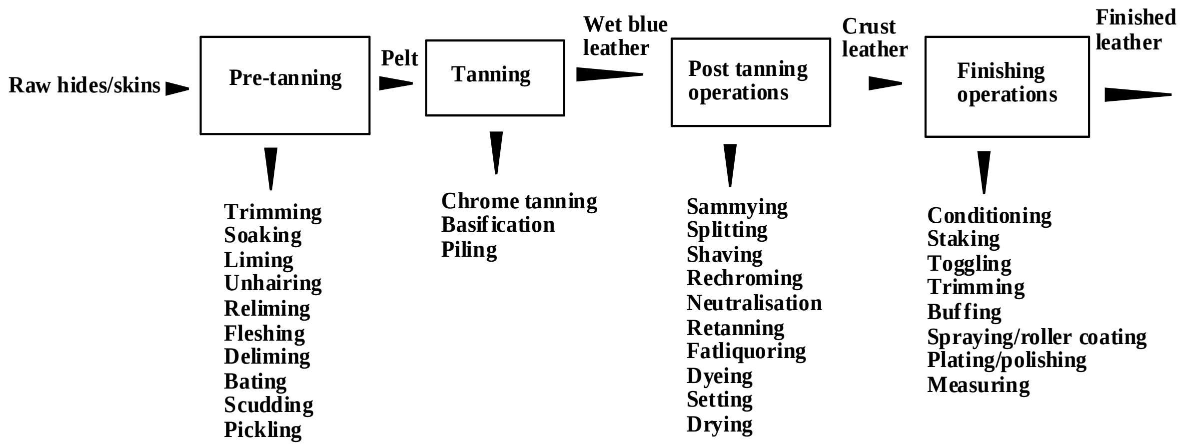


Figure 2.2 Process flow sheet for conventional leather processing

2.4. Beamhouse and Tanning Processes

2.4.1 Soaking

Soaking is the first stage in the leather manufacturing processes. There are two main purposes for the soaking process (Daniels, 2003; Thanikaivelan *et al.,* 2005):

- Re-hydration of hides and skins to bring them back to the state of fresh hides or skins just after flaying) as far as possible, and
- Removal of adhered blood, urine, soil, dung, salt or other extraneous materials from hides or skins.

A soaking process also assists removal of non-collageneous proteins, water-soluble albumins and salt-soluble globulins, constituents of the interfibrilary fluid and fibroblasts (Heidemann, 1993).

2.4.2 Unhairing

Unhairing processes are carried out to remove hair and some non-structural proteins such as proteoglycans from the hides. The main structural protein of hair is keratin. Keratin mainly consists of an amino acid called cystine. Reduction or oxidation can break down the disulfide bonds (S-S) of cystine causing keratin degradation, without affecting the collagen. The most commonly used reducing agents are sulfur or thio-compounds. The removal of proteoglycan splits up the fibre structure into fibril levels and is known as "opening up". Swelling of hides and opening up of the fibre structure takes place during liming. A hair-burning method for removal of hair is caused by the total destruction of keratin. Usually in a conventional hair burning method, unhairing and liming is carried out at the same time in a drum or paddle. This process requires 14-24 hours at room temperature for complete hair removal and opening up. Mechanical movements increase the reaction rate as well as assisting in the removal of hair roots from the hair follicle (Frendrup, 2000; Heidemann, 1993).

A hair-saving method of unhairing is the removal of intact hair and considered as an environmentally friendly method of unhairing. A conventional hair-saving method, known as "painting" is mainly carried out to remove hair from sheep or goatskins. In this process of hair removal, a thick paste of lime and sulfide is applied on the flesh side of skins, folded flesh side to flesh side, and left for 4-6 hours. Sulfides penetrate through the skins and attack the hair roots and epidermis causing removal of intact hair (Daniels, 2003; Heidemann, 1993; Frendrup, 2000). Subsequent liming is required for swelling of unhaired skins (Heidemann, 1993).

2.4.3. Fleshing

Fleshing is carried out to remove excessive organic materials (fats and tissues) and to aid chemical penetration into the hides. Fleshing may be carried out at various stages such as prior to soaking, after soaking, after unhairing or after pickling. The fleshing process, if undertaken prior to unhairing, is known as green fleshing, and lime fleshing if carried out after liming. Green fleshing reduces the chemical uptake during liming and assists in achieving a uniform liming effect to enhance leather quality. This also produces fleshings at neutral pH that are free from chemical contamination. By-products such as protein and fat may be extracted from green fleshings (Ludvik and Buljan, 1998).

2.4.4. Deliming

Deliming processes are carried out to neutralise lime and other alkalis from hides and skins, which were absorbed during the liming process. The deliming process also prepares the pelts (unhaired hides/skins) for the subsequent bating process. Weakly bound alkalis can easily be removed by washing the pelts with water. Acid salts such as ammonium salts (ammonium sulfate or chloride), or sodium bisulfite are used to neutralise chemically bound alkalis. Ammonium salts are the most common deliming agents since the salts buffer the pH to 8-9, at which the commercial proteolytic enzymes (added in the subsequent process bating) operate at optimum levels. Organic acids such as lactic acid, acetic acid or boric acid, and strong mineral acids such as hydrochloric acid may also be used. Careful controls are required while using strong mineral acids as they may reduce the pH of the deliming liquor to a very low pH. A low pH cause the precipitation of proteins onto the grain and acid swelling, as a result, the grain may be damaged (Leafe, 1999).

2.4.5. Bating

The main purpose of the bating process is to clean the grain by removing scuds (e.g., hair roots, pigments). Proteolytic enzymes with a mild cleaning action are used in bating. The commercial bating enzymes are mainly based on pancreatic trypsin or bacterial proteases. These enzymes require an optimal pH range of 8-9 (Daniels, 2003). The enzymes may also break down other non-structural and structural proteins which relax the skin and soften the leather (Daniels, 2003; Leafe, 1999).

2.4.6. Pickling

Chromium is the most commonly used tanning agent. It is sparingly soluble in water and requires low pH for higher solubility. A high pH in the tanning liquor will cause chromium to precipitate onto the pelt surface, so reducing penetration into the pelts. The pickling process is therefore carried out before tanning to reduce the pH of the liquor, in order to allow the penetration of the chromium salt into the pelts. The pH is generally reduced by adding acids, such as sulfuric and formic acids. The pH of the pickle liquor for chrome tanning is approximately 2.5. The low pHs cause the swelling of the skins, known as "acid swelling". Sodium chloride (NaCI) (6-8%) based on the pelt weight) is therefore added during a conventional pickling process to control acid swelling (Leafe, 1999; Thanikaivelan *et al.,* 2005).

2.4.7. Tanning

Tanning of hides and skins is defined as the conversion of putrescible biodegradable materials (hide/skins) into a non-putrescible material that is leather, which can resist microbial attack. Tanning causes changes in physical appearance and properties, such as opacity and increase in hydrothermal stability. The newly acquired properties due to tanning should be permanent so the leather should have resistance to prevent it reverting back to the properties of the raw pelts (Covington, 2001; Heidemann, 1993).

2.5. Cleaner Technology Options

The generation of pollution is higher in the pre-tannning when compared to wet-finishing and finishing operations. The contributions of BOD and COD by pre-tanning are around 55% and 52% respectively out of the total load (Chandrasekran 1989). Technologies or eco-friendly methods such as desalting, enzymatic unhairing, ammonia-free deliming, pickle recycling, pickle-free tanning system etc. are some of the important cleaner processing options. In post-tanning, researches have been geared up to develop eco-friendly and bio-degradable wet finishing auxiliaries. Engineering modifications of processing vessels too have been the topic of research and improvised processing vessels such as hide processor and compartmental drums have been developed, that could result in increased uptake of auxiliaries. Chromium as well as the neutral salts present in BCS tends to increase the amounts of COD, TDS and sulphate content in the spent chrome liquor (Chandrasekran 1989). The international specifications for permissible levels of chromium in industrial wastewater stipulate values in the range of 0.3-2.0 ppm (Buljan 1996), but now nearly 1500–3000 ppm of chromium(III) (Rao 1997) is discharged in the chrome bearing effluents. The improved chrome tanning methods lead to increased uptake of above 90% thereby the chromium content is around 500-1000 ppm in the spent chrome liquor. The various chrome management technologies are high exhaust chrome tanning, recovery/reuse, recycling/reuse, less chrome and chrome less tannages (Rao et al 2002). Now a days the dicarboxylic acids, aluminium syntans etc. are used for increasing the exhaustion of chromium in the chrome tanning system.

Chrome recovery and reuse (Rao 1987, Covington et al 1983) and closed pickle–tan loop (Rao et al 1999) approaches have been developed. The recovery and reuse of the chrome may be very useful as this could be used again for the tanning purpose. Direct recycling of chrome liquors is also gaining importance (Rao et al 2002).

Less chrome technology is the type of tanning done to reduce the amount of total chrome offered and so in the effluent. Here, a combination type of tanning is adopted so that the amount of chrome in the effluent is minimized to the maximum extent. Other tanning agents are added with chrome to reduce the offer of chrome. Ecological studies have shown that random disposal of waste chrome products can be a danger to mankind. Research to overcome this problem has created the wet- white approach for the production of leather, using a pretannage with aldehyde, Al, Ti, or Zr salts then retanning with mineral tans, syntans and vegetable tans. Several researchers have examined chromium/iron combination tanning system (Fleming 1943, Thanikaivelan et al 2003).

The difficulty in treatment of tannery wastewater is due to complex nature of the industry and a large number of chemicals employed in the leather processing. The segregation of each sectional stream and separate treatment therefore requires very high investment in term of equipment, land etc. hence eliminating or reducing the wastage at the source i.e. at the stage of leather processing, is a promising option for the tanneries. Some of the cleaner technological options are discussed in the Table 1.1.

Table 2.2 Cleaner technological option and its advantages

Cleaner Technology option	Impaction on pollution Load
Salt free hide and skin preservation	Helps eliminate salt and reduce TDS
Mechanical desalting	Helps eliminate salt and reduce TDS
Counter current soaking	Reduced water consumption
Enzyme assisted soaking	Reduced water consumption and processing time
Green fleshing	Reduced chemical consumption and solid waste
Enzymatic sulpide free unhairing	Reduced concentration of sulphide, COD etc in effluent
Lime splitting	Reduced chemical consumption and solid waste
Hair saving unhairing -liming	Reduced concentration of nitrogen, BOD, COD, etc in effluent.
Direct recycling of liming floats	Reduced chemical and water consumption and reduced BOD, COD, and sulphide in effluent
Ammonia-free deliming using carbon dioxide	Reduced concentration of nitrogen, BOD
Chrome recovery, high chrome exhaustion and/or chrome liquor recycle	Reduced concentration of chromium in the effluent.

2.6. Main Characteristics of tannery wastes

The principal constituent of a particular tannery waste stream depends on the type of raw material, processing stage, and the method of processing. Generally, the composition of waste generated during the leather manufacturing process typically comprises of liquid, solid waste, and gases.

2.6.1. Liquid waste

The entire process of tanning is often accompanied by the consumption of large volumes of water, normally in the range of 50% - 200% of the weight of the material (Covington, 2009). As an example, processing 1 tonne of raw hides using the conventional tanning techniques generates about 30 m^3 of effluent containing up to 400 kg dissolved and suspended solids (Puntener, 1995). Most of the dissolved and suspended solids found in the liquid are protein residues, and extraneous matter, hair, blood and dung, removed during the beam house operations (Christner, 1988). Other constituents include ammoniacal nitrogen, salts, sulfide, chromium and dyes (Puntener, 1995). Figure 1.7 shows the percentage distribution of liquid waste generated from major processing steps.

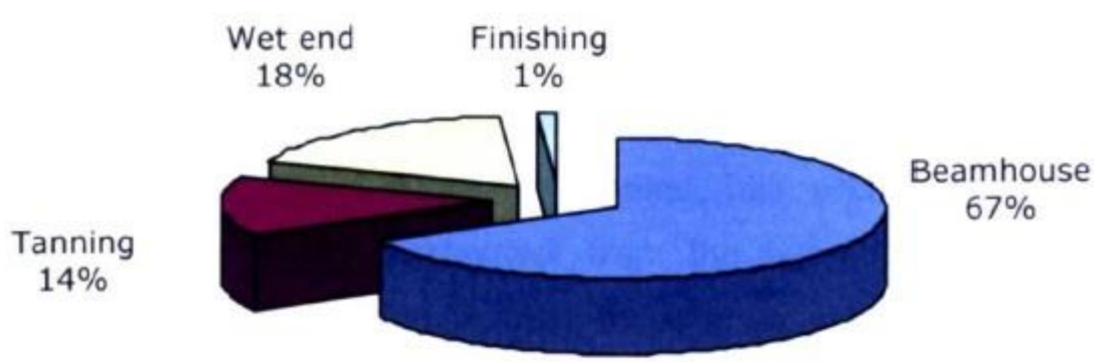


Figure 2.3 Effluent generated at each processing stage from 1 tonne of raw hides (Puntener, 1995)

2.6.2. Solid waste

The main constituents of solid wastes are fleshing, fats, solid hair debris, trimmings, shavings, and leather cuttings. An additional source of solid waste is the sludge from the effluent treatment plant (Buljan and Ludvik, 2000). The solid waste generated from processing 1 tonne of raw hides using the conventional processing techniques is approximately 700 kg, with the largest quantity being generated from beam house operations (Figure 1.8) (Puntener, 1995).

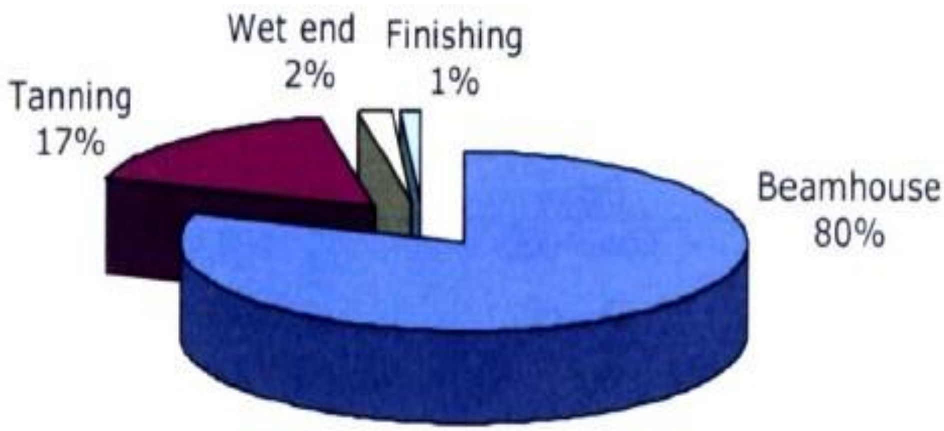


Figure 2.4 Solid waste generated at each processing stage from 1 tonne of raw hides (Puntener, 1995).

From Figures 1.7 and 1.8 it is clear that the largest source of polluting effluent in the entiretanning process, originates from the beam house processes.

2.7.Structure of camel skin

Anatomical studies of camel skin are few in numbers. The skin of camel is unique among domestic animals. The epidermis of camel usually consists of following layers (Murray, 1998).

i. *Stratum corneum* (horny layer) represents 1/2-3/4 of the total epidermal thickness. This layer consists of fully keratinized cells pushed up from basal layers.

ii. *Stratum lucidum* is occasionally seen in sparsely haired skin as a dense eosinophilic layer beneath the stratum corneum.

iii. *Stratum granulosum* (granular layer) is a single layer of cells in some areas and dicontinuous in others. The nuclei are pycnotic, and most of the cytoplasm has been replaced with keratin.

iv. *Stratum spinosum* (prickle layer) is reduced but is composed of daughter cells of the basal layer and is 1-3 cells thick. These cells are viable and nucleated and activity synthesize keratin.

v. *Stratum germinativum* is the deepest layer of the epidermis and consists of a single lay of cuboidal or columnar cells, most of which are keratinocyts with a few melanocytes. Melanocytes contain melanin pigment in pseudopods distributed between epidermal cell of the skin and hair.Skin colour is determined by the number, size, arrangement and dispersion of melanin granules (Goswami et al 1994). The dermis (corium) is thick (up to 1 cm in the cervical region of a mature male camel) and consists of a superficial layer composed of loose connective tissue interdigitating with undulations in the epidermis and the deep dermis, which composed of dense fibrous tissue. The dermis contains hair follicles, blood and lymph vessels, nerves and sebaceous and sweat glands. The mid-dermis is characterized by a proliferation of blood vessels, in contrast to that in other domestic animals. The hypodermis (subcutis) is composed of loose connective tissue, which attaches skin to the underlying bones or muscles. Some sweat glands extend into the hypodermis.

2.8. advantages of camel hide

Camel hides, if tanned and converted into leather or furs have the following advantages:

i. It has good 'substance' which means thickness, toughness, compactness and texture of the hide are of good quality.
ii. Camel skin is versatile in use, which means that skin of young calves are useful for making furs and those of adults are used for making leather.
iii. The unique translucent structure of camel hides makes them especially used for making the articles such a lampshades, toys, drum leather and containers of various types (Bhakat and Sahani ,2005).

The conventional raw material resources to the Sudanese tanning industries comprise of cattle hides, sheep and goat skins. However, Sudan possesses other livestock populations such as camels, donkeys, horses and exotic animals. Because of the religious and ethics existing in the country, the people in Sudan do not consume the meat of donkeys, horses and exotic animals. But, camel meat is consumed as part of food and hence the hides from camels can be considered as alternative and additional raw material source to the existing raw hides and skins (Bewketu *et al*., 2013).

Tanning industry is a raw material and labour intensive industry. Raw materials account for 50-70% of production cost, labour 7-15%, chemicals about 10%, energy 3%. To maintain a good market share in the world, a better approach is needed in the selection of cheaper and quality raw materials. Currently, the price of camel hides is the cheapest among the existing raw materials. This is due to the lack of awareness and less off-take rate and hence is utilized for poultry feed, glue manufacture and for the production of low value traditional materials (European Commission 2003).

2.9. Natural Products from camel hides

The raw camel hides are obtained from few areas in small number from "fallen" stock, which have been allowed to linger on till die of old age or disease or by accident, since in India camels are not slaughtered from meat or any other purpose. Flaying of camel hides is generally done manually by the people engages in the business of collection of raw hides. The flaying of camel hide is not an easy job due to its large body size (Bhakat and Sahani ,2005).

There is little data available on non-carcass components of the camel. Proportions of live weight as feet and hide are higher for the camel than for cattle, but the head is proportionately lower than cattle (Mahgoub *et al.*, 1995a, Mahgoub, Olvey, & Jeffrey, 1995b). The latter difference is most likely due to lack of horns in the camel. The head, hide and feet contributed 2.4%, 7.3% and 3.4% of live weight in the dromedary camels evaluated by Herrman & Fischer (2004).

The skins of young camel calves can provide the best raw material for making good quality furs as it hold lustrous, fine and soft hair covering of excellent quality and silky feeling in nature (Bhakat and Sahani ,2005).

The hair is naturally coloured in varying shades and tones ranging from light fawn to dark brown colour. The semi-dried camel calf skins have to pass through chemical and mechanical treatments before they get actually converted into a fur. Adequate precautionary measures are to be taken to preserve the original characters of hair, viz. colour, luster, silkiness, etc. and also to impart other properties of a fur such as flexibility, elasticity, softness, suppleness, etc (Bhakat and Sahani ,2005).

The hides and adult camels have excellent properties of leather making. The leather making process is comparatively more complex and lengthy procedure than fur making. It involves a larger number of operations, many labours and huge machinery. The additional operations in making leather are treatments of cured camel hides with lime and sodium sulphide (liming process) for dehairing, removal of final traces of lime treatment with certain enzymes (bating process), dyeing, resin finishing and/or lacquer finishing. The resin finishing consists of treatment of applying staining coat, seasoning coat by using some resin bindery hot plating (ironing) and glaze finish. In order to add water-repellent properties to the finished leather, it is subjected to lacquer finishing also (Bhakat & Sahani, 2003.).

The commercial tanning of camel leather was pioneered in Australia. It is very versatile leather which has two unique properties. These are its exceptional tensile strength and the attractive grain pattern on the tanned product. These features ensure its demand for the manufacture of a wide range of products.

Historically footwear manufacturing has been estimated to consume 60 to 65% of all the leather tanned in the world, its importance has shrunk over the years and was estimated at 48% in the 2004-7 period. Nevertheless it still remains the biggest single user of leather, thus it is used as a proxy of the level of demand at the end market of the chain. It is assumed that an increase in the consumption of footwear would increase demand of leather (Global Hides and Skins Market, 2008).

There is great potentiality of utilization of camel skin as furs, keeping in view the excellent fur making properties of camel calf skins. The camel furs with their inherent natural colour, luster and softness are most suitable for wall hanging, fur garments and furniture coverings, etc. The superior leather making quality of adult camel hides are useful for a wide range of articles, viz. mojari, handbags, saddlery harness, etc. and several other items. Camel hides also serve as an important base material for many valuable decorative objects. The objects such as lamp shades, containers of various types, shapes and size, show pieces and similar other decorative articles are made of dried untanned camel hides and their surfaces are painted in gold.

Camel skin has no major commercial use for leather production. But it may have a value for tourists. Camel hides are very strong with a tensile strength, five times greater than cattle hides. Camel leather is being crafted for fashion garments such as leather wallets, handbags, purses and shoes. Since these products in general are made from goat leather, camel leather products should be branded as such. Tourists could purchase handmade camel leather products such as fashion accessories and souvenirs directly from the farm (Ishag I.A 2009).

The efficiency of using different tanning and finishing methods for manufacturing of Egyptian camel leather has been evaluated. Three different tanning methods (chrome, vegetable and combined) were used to tan pelts according to its grade. Four different finished leather articles (nappa, nubuck, corrected grain and suede) were produced from chrome tanned leathers to improve their appearance. The results of both physical and chemical properties illustrated that the combined tanning method produced the highest leather quality followed by chrome and vegetable tanning, respectively. Furthermore, the nappa leathers had the highest quality followed by nubuck, suede and corrected grain, respectively. Additionally, the produced leather articles showed no visual defects in grain side. These results clarify the ability of using Egyptian camel leathers for manufacturing of garments, shoe upper, upholstery, lining and sole manufacturing (Nasr 2015).

2.10. Leather Industry Sector

The leather industry plays an important role in our daily life. And as an important industrial material product, leather is widely used in many fields, including shoes, clothing and furniture upholstery (Baker 2018, Santos *et al*., 2015).Tanning is a meaningful process in the leather industry, which improves thermal stability, mechanical properties and porosity of leather (Combalia et al 2016). In the leather industry, basic chromium sulphate is preferred as tanning agent, mainly because of its lower cost and better reactivity with collagen fiber (Bacardit et al 2014). However, it is difficult to dispose the solid waste containing chromium generated in leather manufacturing, and chromium (III) might be converted into chromium (VI), which can cause harm to human skin and lead to some other diseases (Hedberg 2020).

Up to now, many chemicals for chrome-free tanning systems have been developed. As a matter of fact, traditional aldehyde tanning agents and vegetable tanning agents can be used to produce chrome-free leather. However, leather tanned with aldehyde tanned leather has the risk of releasing free formaldehyde, and vegetable tannins are not suitable for preparing light leather, which are often used in combination with other tanning agents

(Covington 1997). Besides, non-chrome metal such as aluminium salt, titanium salt, and zirconium salt can also be applied to the production of chrome-free leather (Madhan 2001).

2.11. Leather Making Raw Material

The skin is the largest organ in the body and arguably the most complex. Its primary function is as a barrier from environmental factors, such as viruses, bacteria, chemicals and UV radiation (Menon, 2002). It prevents rapid loss of water and is involved in thermo-regulation (Gustavson 1956). Furthermore, it resists physical stresses and continually repairs itself (Horie,1990).

The size and thickness of the skin depends on the animal species, age and sex. Generally younger animals have smaller and thinner skins, with a finer fibre network. The typical composition of animal hide is shown in Figure 2.1 **(**Sharphouse 1971**)**.

2.12. Collagen: The Leather Making Protein

Collagen is the protein, which is used as the substrate for making leather. The word collagen is derived from the Greek word meaning to produce glue. In the past the collagen from bones and tendons was used in industry to produce glue. Also in organisms, collagen is a kind of glue.

The protein collagen is the main substance of connective tissues and is present in all multicellular organisms. It is the protein that enwraps the organs and parts of it to hold specialized cells together in discrete units. It prevents organs/tissues to tear or loose their functional shape when they are exposed to sudden and wild movements. Collagen gives different organs and tissues substantial, stout and elastic properties.

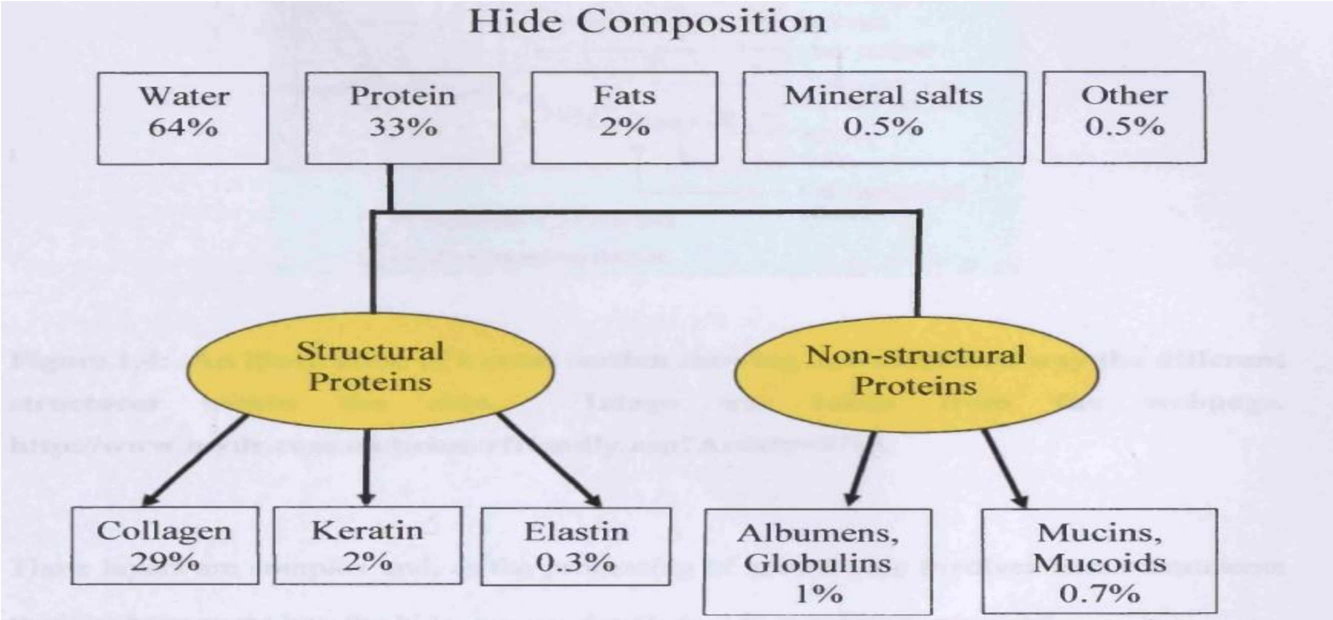


Figure 2.5 Composition of animal hide (Sharphouse 1971**)**

Besides the structural role in mature tissues, collagen plays a regulating role in developing tissues as well. Collagen functions as a kind of trigger that influences the proliferation and differentiation of unspecialized cells. It has a key function in the regulation of cell-type specific gene expression and developmental control (Eyre 1980).

2.12.1. Type I collagen

When the term collagen is used, it usually means type I collagen, the most common of the collagens in vertebrates. It comprises up to 90% of the skeletons of the mammals and is also widespread all over the body. In addition to bones, it is found in skin, tendons, ligaments, cornea, inter-vertebral disks, dentine, arteries and granulation tissues as the main locations. Even cartilage, which mainly contains type II collagen, has been mentioned to contain some type I collagen (Wardale and Duance 1993). Type I collagen is also important in other respects: for example, it is used in the gelatin industry and in many biomaterials and leather, is in fact, mostly composed of type I collagen. The importance of type I collagen for medical research is that it is involved in many human and animal diseases, including fibrosis, osteoporosis, cancer, atherosclerosis, etc. (Exposito *et al*., 1992)

Similar to other fibrillar collagens, this molecule comprises three polypeptide chains (α-chains) that form an unique triple-helical structure (Figure 2.2). It is a heterotrimer of two α1(I) and one α2(I) chains. Among species, the α1(I) chain is more conserved than the α2(I) chain (Exposito *et al*., 1992).

2.13. Tanning Process

Tanning as a process has been said to be 'easily described than defined'. A precise definition for the process of tanning is still eluding. The word 'tan' and its inflectional form 'tanning', which are derived from Latin word for 'oak bark' were at first applied and is still applied to describe the process of converting a putrescible animal skin into a non-putrescible leather.

In practice, the definition of tanning has the following components (Ramasami 2001):

- Conversion of putrescible biological material (hide or skin, typically) into a non-putrescible material, i.e. acquisition of resistance to microbiological attack (that is degradation by enzymatic action)

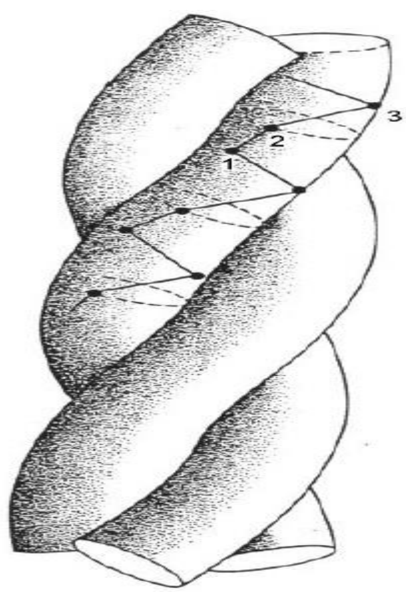


Figure 2.6 Triple helix

- Change in the long range ordering of collagen, the leather making protein, resulting in elevation of hydrothermal stability
- Change in the physical appearance and properties, opacity and handle (even smell)
- Performance of new properties, i.e. degree of reversibility, resistance to reverting back to the properties of raw pelt, particularly throughout wetting and drying cycles.

In the process of leather making there are several chemicals, which can be used for tanning and broadly classified as (a) mineral tanning and (b) organic tanning. When the stabilization of skin is achieved by the use of a suitable inorganic molecule, the process is known as mineral tanning and if vegetable and other organic molecules are used, it is known as organic tanning.

2.13.1. Mineral Tanning

The following metals viz., Cr(III), Al(III), Fe(III), Ti(IV), Zr(IV), Si(IV) and Ce(III)/(IV) have been shown to exhibit tanning potency (Chakravorty and Nursten 1958). Amongst all tanning elements, chromium(III) stands tall as it provides high degree of thermal stability to the collagen matrix and also the ease in carrying out the process resulting in leathers for different end uses.

2.13.2. Organic Tanning

Tanning using vegetable tannins, quinones, aldehydes, oil etc form part of organic tanning. Aldehyde tanning is known to be one of the oldest methods of tanning. Earlier it has been shown that the amino groups present in collagen are involved in crosslinks with aldehydes (Bowes and Cater 1968; Fraenkel-Conrat and Mecham 1949). Recently, the effect of different aldehydes in providing stability to collagen has been addressed (Fathima et al 2004). Oil tanning produces leather having characteristics quite different from all other types of tanning and the leather is named as ‘chamois’ leather.

2.13.3. Vegetable Tanning

Most of the definitions of vegetable tannins quote that they are plant polyphenolic molecules having molecular weight between 500-3000 D. This definition was arrived owing to the fact that the tannins having molecular weight above 3000 D are either insoluble or incapable of diffusing through the collagen network, resulting in poor fixation and the tannins having molecular weight lower than 500 D are thought to be ineffective in forming crosslinks between polypeptide chains of collagen, which is a requirement for effective tann\ing.

Plant polyphenols can be classified based on their structural characteristics into : (i) hydrolysable tannins, with subgroups gallotannins and ellagitannins, (ii) condensed tannins (Khanbabaee and Van Ree 2001) .

2.13.4. THPS

THPS, Figure 2.3 (Tetrakis hydroxymethyl phosphonium sulphate) is the condensate of PCl_3 (phosphine), H_2SO_4 and formaldehyde, regarded as aldehyde derivative promoting cross-linking mainly through their CH_2OH groups reacting with amino groups of protein (Hartley 1996).

Studies on tanning properties of THPS were carried out (Das Gupta 1977) as an alternative tanning agent to the traditional chrome tanning system. The effects of THPS on shrinkage temperature of lambskins (Das Gupta 1977) and their combination with aluminium salts were studied.

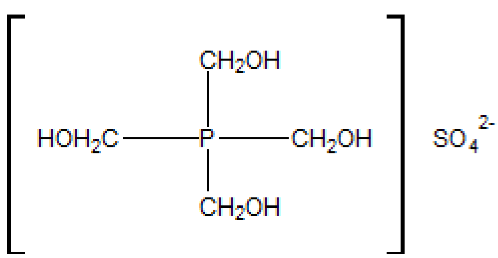


Figure 2.3 Structure

2.13.5. Aldehyde Tanning

Aldehyde Tanning employing formaldehyde and glutaraldehyde are effective organic tannages (Seligsberger and Sadler 1957). Mclaughlin and Theis (1945) supported the theory that formaldehyde formed bridges in the pH range of 4 to 9 and this type of cross-link was responsible for the structural stability of the leather. The ε-amine groups of lysine would bind formaldehyde at pH values above 9.0. According to Gustavson (1956), formaldehyde can react with amine, guanidino, hydroxyl, amide and peptide group of collagen.

2.13.6. Synthetic Tanning Agents - Syntans

Syntans are water soluble high molecular organic compounds. They are used for pretanning, retanning, bleaching, mellowing, filling, mordanting for dyeing, neutralization, grain tightness, minimizing the sludge in vegetable tanning liquors, etc. Also syntan based on acrylics, PU etc., should not have film forming properties in leather.

The first patent in this field was made by Stiasny on 1911 and the first commercial product based on sulphonated cresol condensate, was introduced by M/S BASF of Germany on the year 1912 under the trade name “Neradol D”. The syntans are classified into three categories (Otto 1937).

- Auxiliary
- Combination
- Replacement (substitute or exchange)

Chapter Three

Materials and Methods

3.1 Materials

Wet salted camel hides obtained from a local abattoir located at Khartoum were used as raw material for experimental processes and wet salted cow hides were used as raw material for control processes. The chemicals used for tanning and post tanning processes were of commercial grade, i.e. chemicals to be consumed during the leather making starting from soaking to finishing as in the conventional method of leather manufacture.. The chemicals and reagents used for the analysis of spent liquor were of analytical grade.

Laboratory instruments and apparatus used for chemical analysis include viz., Drums for leather processing, Sample holders, Common glass wares, Soxhlet apparatus, Hot air Oven, Burettes, Micropipettes, Heating mantle, SEM, Magnetic stirrer and filter papers. Laboratory instruments and Apparatus used for physical analysis include viz., Shrinkage temperature tester; Universal Tensile strength machine, and Lasto-meter. Leather processing equipments and apparatus include viz., drums, paddles, Fleshing machine, Shaving machine, Sammying machine,Vacuum dryer, Spraying machine ,Roller cotter machine and embossing machine.

3.2 Methods

Fresh camel hides were washed and preserved as usual by applying sodium chloride and processed conventionally and examined for chemical and physical properties in the laboratory to assess the suitability of the raw material for the production of finished leather products for various applications.

Experimental preserved raw camel hides were first rehydrated in a process known as soaking, and the soaked hides were then green fleshed to enhance the penetration of the chemicals used in the subsequent operations. After green fleshing, the raw hides were subjected to liming in order to remove keratinous and other non-collagenous materials present in the raw hides and open up the fibres. At this stage the hides are known as pelts. The pelts were then subjected to various pre-tanning operations such as deliming, bating, and pickling depending on the requirements to condition the same for the subsequent tanning systems. At this stage, the tanned materials are known as leathers. The leathers were shaved to the desired thickness prior to conducting the post tanning operations where the leathers are incorporated with utility properties like softness, fullness, colour, and water resistance.

3.1.1 Histological Studies Tanning processes

Tissue processing for histological study is a procedure of removing water from cells and replacing it with a medium which solidifies allowing thin sections to be cut on a microtome. Once tissue is properly fixed it goes through a process which involves the following steps: dehydration, clearing and infiltration (Figure 3.1) (Andrew, 2019).

Histological examination was carried out on the soaked camel hides (experimental) and cow hides (control). Samples were taken and preserved in 10% formalin for 48 hours. The fixed samples were dehydrated in an aqueous alcohol series (50 to 100%) and then cleared in xylene. Samples were finally embedded in paraffin wax and 10μm sections were cut on a microtome, mounted and stained with H & E stain.(Junqueira and Carneiro 2005)

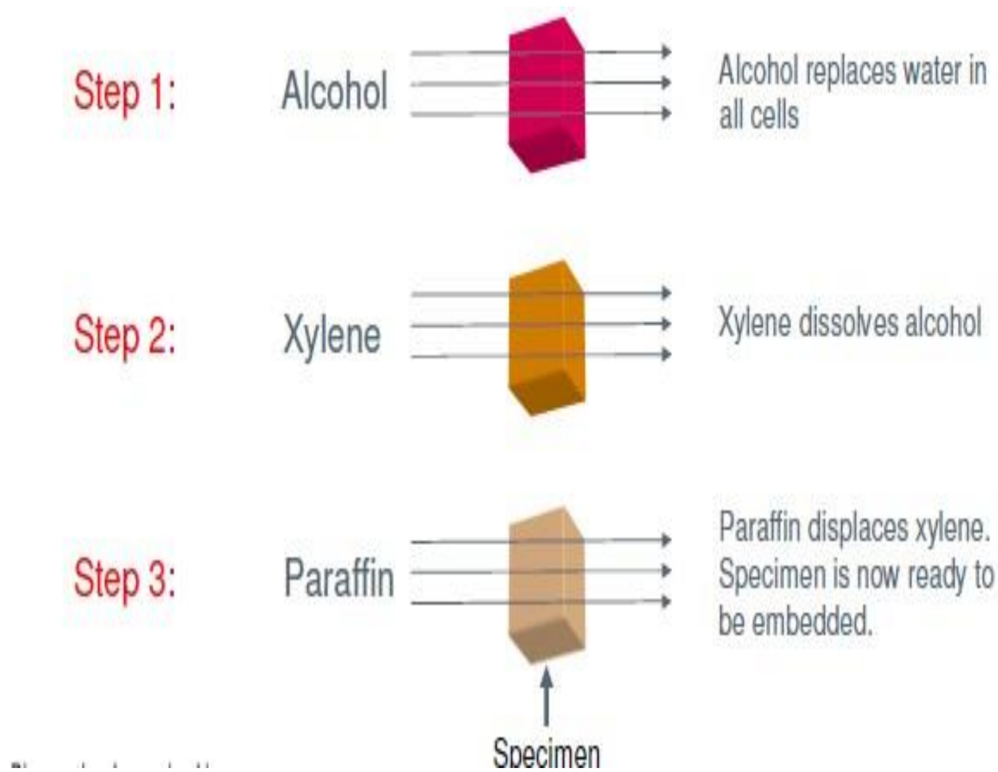


Figure 3.1 Tissue processing steps (Andrew, 2019)

3.1.2 Tanning processes

The conventional chrome tanning process has been carried out using wet salted camel hides (experimental) as given in the **Table 1**. The conventional chrome tanning process has been carried out using wet salted cow hides (control) as given in the Table 3.1 The post tanning process mentioned in **Table 3.2** is followed for both experimental and control leathers.

Table 3.1 Tanning Process for Camel Hides (Experimental) and Cow Hides (Control) for Manufacture of Upper Leathers

Process	**%**	**Product**	**Duration (min)**	**Remarks**
Soaking	500	Water	1 hr	
Liming and unhairing	100 4 2	Water Lime Sodium sulphide	4 hr	pH 11-12
Deliming and bating	100 1.5 1	Water Ammonium sulphate Bating agent (oropon)	2 hrs	pH 8-8.5 Check with indicator phenolphthalein, gave colorless
Washing	200	Water	15 min	
Pickling	100 10 0.75	Water Salt Sulphuric acid (dilute 1:10 with water)	2 hrs	pH 2.8-3
Tanning	8	Basic chromium sulphate	4 hrs	
Basification	1 0.5	Sodium formate Sodium bicarbonate	45 min 60 min	pH 4
Washing	300	Water		Drain, piling overnight, sammed, set out, shaved 1.2 mm and shaved weight noted

Table 3.2 The Post-tanning Process for Experimental (Camel) and Control (Cow) for Manufacture of Upper Leathers

Process	%	Product	Duration (min)	Remarks
Washing	200	water	10 min	
Neutralization	0.75	Sodium bicarbonate	3×15	pH 5-5.5
Retanning, Dyeing and fatliquoring	100	water		
	8	Syntan	90 min	
	3	Acid dye brown	45 min	
	9	Synthetic fatliqour	90 min	
Fixing	1	Formic acid	3×10 + 30	pH 3.5
Washing	300	water	10	Drain the bath and pile overnight. Next day samming and setting out, toggling, staking trimming , buffing and finishing .

3.1.2.1 Measurement of hydrothermal stability of leathers

The shrinkage temperature of control (cow) and experimental (camel) leathers has been determined using Theis shrinkage tester (McLaughlin 1945). 2X0.5 cm^2 piece of tanned leather cut from the official sampling position has been clamped between the jaws of the clamp and has been immersed in solution containing 3:1 glycerol: water mixture. The solution has been continuously stirred using mechanical stirrer attached to the shrinkage tester. The temperature of the solution has been gradually increased and the temperature at which the sample shrinks has been measured as the shrinkage temperature of the leathers.

3.1.2.2 Physical testing and hand evaluation of leathers

Samples for various physical tests from experimental and control crust leathers have been obtained as per IULTCS methods (IUP 2 2000) (Fig. 3.2). Specimens have been conditioned at 20 ± 2 ºC and 65 ± 2 % R.H over a period of 48 hrs. Physical properties such as tensile strength, percentage elongation at break (IUP 6 2000) , grain crack strength (SLP 9 (IUP 9) 1996) and tear strength (IUP 8 2000) have been measured as per standard procedures. Each value reported is an average of four samples (2 values along the backbone and 2 values across the back bone). Experimental and control crust leathers have also been assessed for softness, fullness, grain smoothness, grain tightness (break), general appearance and dye uniformity by hand and visual examination. Three experienced tanners rated the leathers on a scale of 0-10 points for each functional property, where higher values indicate better property of leathers.

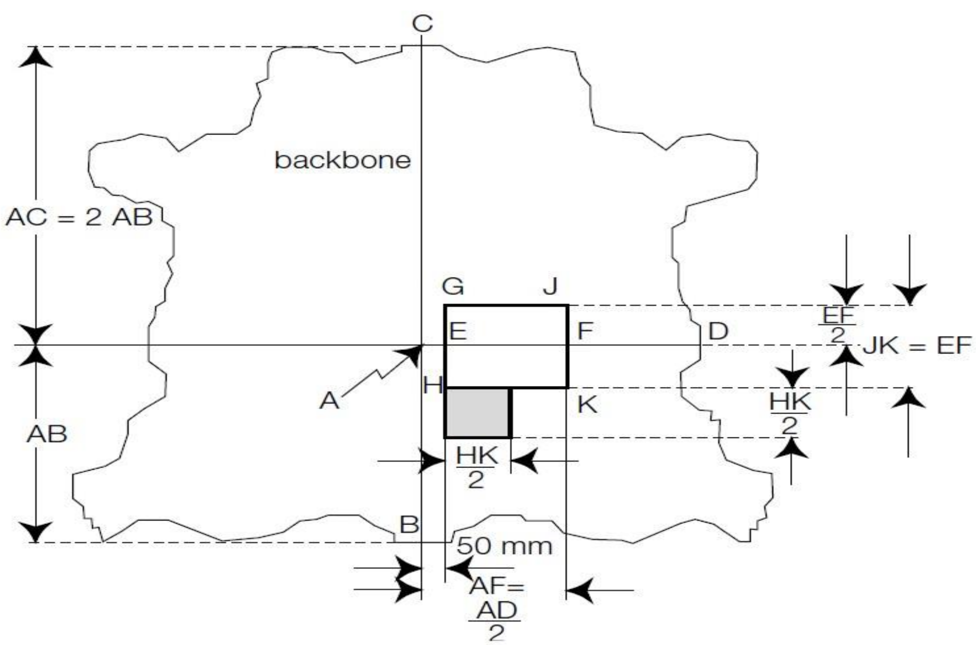


Figure 3.2 Sampling location for hide of cow and sheep

3.1.2.2.1 Conditioning

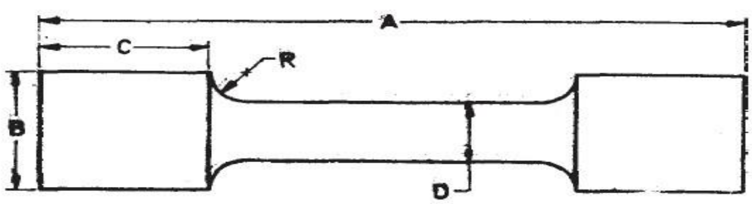
The specimens for physical testing were kept in a standard atmosphere of temperature 20±2ºC and relative humidity 65±2% over a period of 48 hrs.

3.1.2.2.2 Measurement of Tensile Strength

The samples were cut parallel and perpendicular to back bone used a dumbell shape (Fig. 3.3) (IUP 6, 2000). The thickness and width of the specimen were measured in the same position using standard thickness gauge and vernier calipers respectively i.e. Measured one at the midpoint and other two mid way. The width must be measured on the flesh and grain side, and then. The mean thickness (mm) and width (cm) are calculated. The area of cross section of each specimen was calculated by multiplying its width by thickness.

The jaws of the tensile machine Instron 10261 (Fig. 3.4) were set 50mm apart, and then the sample was clamed in the jaws, so that the edges of the jaws lie along the mid line. The machine was run until the specimen was broken and the highest load reached was taken as the breaking load. Calculation:

$$Tensile\ Strength\ (kg/cm^2) = \mathbf{(}\,Breaking\ load\ (kg)\,\mathbf{)/(}\,thicknes \times width\ (cm^2)\,\mathbf{)}$$



	A	*B*	*C*	*D*	*R*
Large	190	40	45	20	10
Medium	90	20	20	10	5
Small	40	10	10	5	2.5

All dimensions in millimetres.

Figure 3.3 Shape and dimensions of internal surfaces of press knives

3.1.2.2.3 Percentage elongation at break

The initial free length between the clamps before and after final free length at the instant of break was measured. The initial free length was set at 5 cm and the elongation calculated from graphical read out.

Calculation:

Percentage elongation at break = (Increase in length at break/original length) $\times$ 100

Figure 3.4 Tensile strength machine

3.1.2.2.4 Measurement of Tear Strength

This method (IUP 8, 2000) was intended for use with any types of leather. The specimens were cut as a rectangle 50 mm long and 25mm wide by used of a press knife which cuts out the specimen and slot in one operation (Template machine) parallel and perpendicular at each position. Instron 1026 having a uniform speed of separation of the jaws of 100±20 mm per minute was used and the reading of load fall in that part of the scale which has been shown by calibration to be correct within 1%. The machine was run until the specimen was torn a pat and the highest load reached during tearing was recorded as the tearing load is in Newton or kilograms.

Tear strength (kg/cm) = Load (kg)/ Thickness (cm)

3.1.2.2.5 Measurement of Distention and Strength of Grain by the Ball Burst Test (Lastometer)

This method was intended to assess how mach a material can stretched simultaneously in two directions without damaged (IUP 9, 2000) using lastomer (Fig. 3.5). Principle of method: a circular specimen of the sample was clamped round its edge and gradually distended by forcing a small metal attached to a plunger through specimen. The distended crack appears on the Surface. Test specimen 44.5mm diameter, test cut from testing area of leather. Test conditioned at 20±2°C and 65±2% RH for 48 hours. Procedure: Tightly clamp the test specimen in the machine. Start the machine forcing plunger at rate of 0.2 + 0.05mm/s. The initial crack on the grain appears on surface of specimen min 20 Kg. The Distension at grain crack min 7 mm.

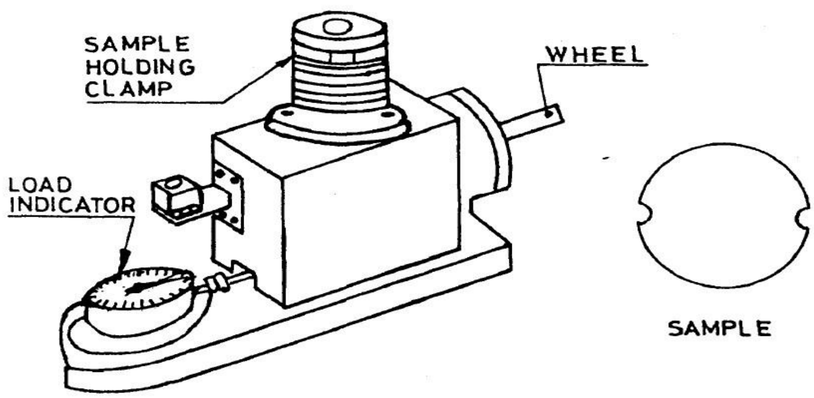


Figure 3.5 Typical Lastometer

3.1.2.3 Scanning Electron Microscopic Analysis of Leather Samples

Samples from experimental and control crust leathers were cut from official sampling position. Samples were directly cut into specimens with uniform thickness without any pretreatment. All specimens were then coated with gold using Edwards E306 sputter coater. A Leica Cambridge Stereoscan 440 Scanning electron microscope was used for the analysis. The micrographs for the cross section were obtained by operating the SEM at an accelerating voltage of 20 KV with different lower and higher magnification levels.

3.1.2.4 Evaluation of chemical constituents in leathers

The chemical constituents such as total ash content % , Moisture %, Fats and oils % and Chrome oxide (Cr_2O_3) have been carried out for control and experimental leathers according to standard procedures (Official Methods 1965).

3.1.2.4.1 Determination of Moisture

This method was intended for use in the determination of the moisture content of ground natural materials (Official Methods, 1965).

About 5g of the material was accurately weighed in a weighing basin and dried in air- oven for hours at temperature of 100-105°C. Then cooled in desiccators and weighed. From the loss in the weight the percentage moisture content is calculated as followed:-

Weight of empty basin (g)	a
Weight of basin + sample (g)	b
Weight of basin + sample of after drying (g)	c,

% Moisture content (b-c)/ (b-a) X 100

3.1.2.4.2 Determination of Ash Content

Portion of prepared sample (5g) were place in porcelain in crucible of determined constant weight. First, the sample was carbonized on a hot plate under a fume cupboard and then place in furnace at about 800°C until constant weight was achieved. If it was difficult to burn off all carbon, concentrated ammonium nitrate solution was added to the residue and it was heated again if, even after this step, complete burning off was not achieved, hot water added to the reside, the solution was filtered and the reside, on ashles filter paper was washed. Then it was placed in the same crucible, and then dried to constant weight.

Calculation:

Weight of leather sample taken = w_1

Weight of crucible + sample = w_2

Weight of crucible + sample after incineration = w_3

$$\%\ total\, ash\, content = \frac{w_2 - w_3}{w_1} x100$$

3.1.2.4.3 Determination of Fat Content

A portion of prepared sample (10g) was place into a soxhlet apparatus to be extracted by petroleum ether (B.P 40-60°C) for 5 hours, at least 30 siphons. After extraction, the solvent was concentration under vacuum to thick syrup in atared round bottom flask and then dried in an oven at 98-100°C. (Official Methods 1965).

Calculation:

Weight of leather sample = w_1

Weight of empty round bottomed flask = w_2

Weight of round bottomed flask after extraction and drying = w_3

$$\%\ \text{oil and fat content} = \frac{w_3 - w_2}{w_1} x100$$

3.1.2.4.4 Chromic oxide content of leather

- **Aim:**

To determine the percentage of chrome content in terms of $Cr_2\ O_3$

- **Principle:**

The determination depend upon the oxidation of trivalent chromium into the hexavalent state using strong oxidizing agent like the acid mixture and the subsequent liberation of iodine from KI which titrate with standard thiosulphate leads to estimation of chromium.

- **Reagents:**

10% KI solution

0.1N Thio

20 ml Acid Mixture (Conc. Sulphuric acid, Conc. Nitric acid, Perchloric acid 3.5:5:11.5).

- **Procedure:**

A piece of chrome tanned leather is taken and is cut into small pieces. Known weight is taken and 20 ml of acid mixture is added in a conical flask. The mixture is digested till the colour change green to orange. 20 ml distilled water to wash away the chlorine liberated, it is boiled and cooled, it made up to 250 ml. 20 ml of this digested solution is taken in a iodine flask and 15 ml KI solution is added to it and immediately kept in dark for 2-3 min. it is titrated against thio till brown color is converted into straw yellow. 2ml of starch is added to the iodine flask to get blue color solution. It is titrated against thio. Till the color disappear. Titrate value is noted.

Calculation:

1000ml of 0.1N thio= 1Eq. weight of Cr_2O_3 content = 25.33 gm of Cr_2O_3

Cr_2O_3 = (250*Nthio*25.33*100)/(wt*1000*20)

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Histological Studies

Histological properties of the raw camel hide (experimental) and raw cow hide (control) has been analysed using the H & E staining. The histological examination of the camel hide revealed that is suitable raw material for leather making similar to cow hide. Optical microphotographs of soaked cow hides (control) from butt regions, observed under light microscope (40x magnification) as given in Figure 4.1. Optical microphotographs of soaked camel hides (experimental) from thick regions, observed under light microscope (40x magnification) as given in Figure 4.2. It is seen that the collagen fibres from experimental soaked camel hides are more compact, compared to control soaked cow hides. The fibre compactness feature of the camel leather leads to produce different products

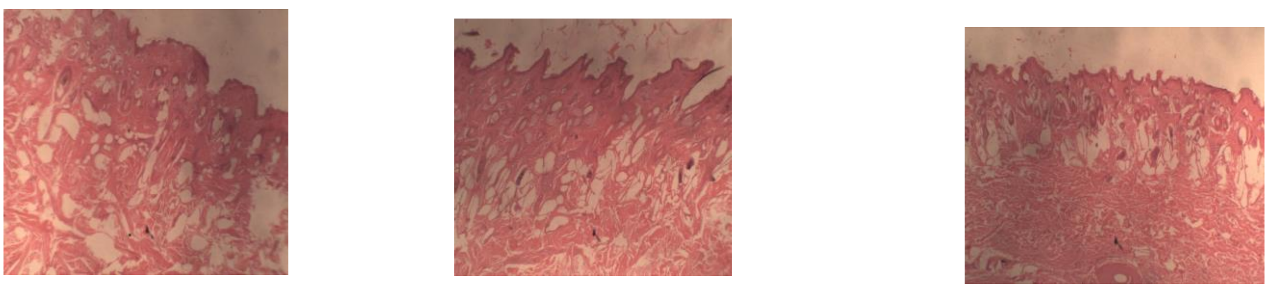


Figure 4.1: Optical microphotograph of green bovine leather at 40* magnification

4.2 Hydrothermal stability of experimental and control leathers

Shrinkage is a phenomenon, associated with dimensional changes of hide, skin or leather when subjected to heating. The temperature at which the material shrinks is termed as “shrinkage temperature” (T_s); and this varies when the hide or skin is tanned. Shrinkage temperature value (T_s °C) of a specimen in water as the heating medium, is taken as measure of hydrothermal stability and the boil test (viz., test for curling of leather in

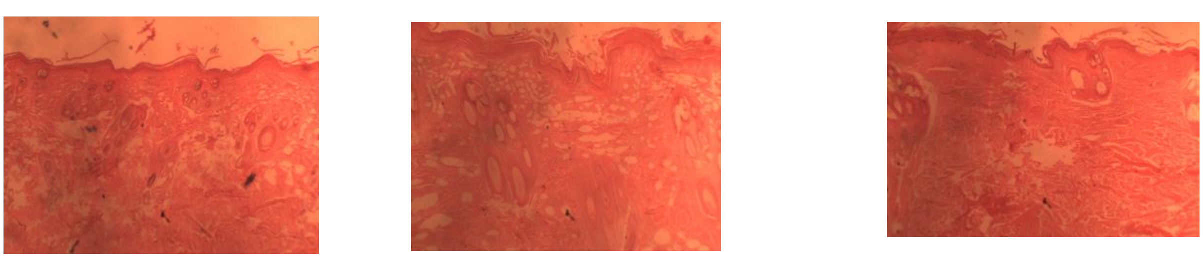


Figure 4.2: Optical microphotograph of green camel leather at 40* magnification.

boiling water) is used even today, to assess the completion of chrome tanning (Kedlaya 1987). The shrinkage temperature of both experimental and control leather is given in Table 4.1.

Table 4.1 Shrinkage temperature of experimental and control crust leathers

Experiment	Shrinkage temperature (ºC)
Camel leather	112±1
Cow leather	111±1

4.3 Organoleptic properties of crust leathers for experimental and control

The organoleptic properties (visual assessment) of upper crust leathers for experimental (camel) and control (cow) are shown in Figure. 4.3. From the figure, it is observed that experimental crust leathers exhibited good softness, fullness, smoothness, general appearance and dye uniformity compared to control leathers.

4.4 Physical strength characteristics of experimental and control crust leathers

The physical strength measurements of experimental camel and control cow leathers are given in Table 4.2. The physical strength measurements viz., tensile strength, tear strength has been found to be better for experimental leathers. The values for load at grain crack for both experimental and control leathers were comparable. All the physical strength parameters for both control and experimental leathers are found to meet the requirement of BIS standards for upper leathers (BIS, 1989). It is seen that the softness of experimental leathers are better than that of the control leathers. This is in accordance with the observations made by subjective evaluation on softness (Figure 4.3).

The tensile strength was measured in a universal tensile strength machine for both along and across the backbone of the leather samples, in triplicate and reported in kg/cm^2. A good tensile strength is an attribute in general for all types of leathers. It is a valuable guide for judging the quality of leathers. It is the strength property of leathers that predicts the performance of the leather for different end use.

The double-edge tear test was done in triplicate for both along the back bone and across the back bone. The tear strength was reported in kg/cm.

Distension and strength of grain at grain crack test is able to indicate the performance of the produced leather for the manufacture of the intended end use. This test method is used especially to evaluate the final leather whether it can stand loads that pears the leather without any damage to the grain. The load at grain crack was reported in Kg and distension at grain crack reported in mm.

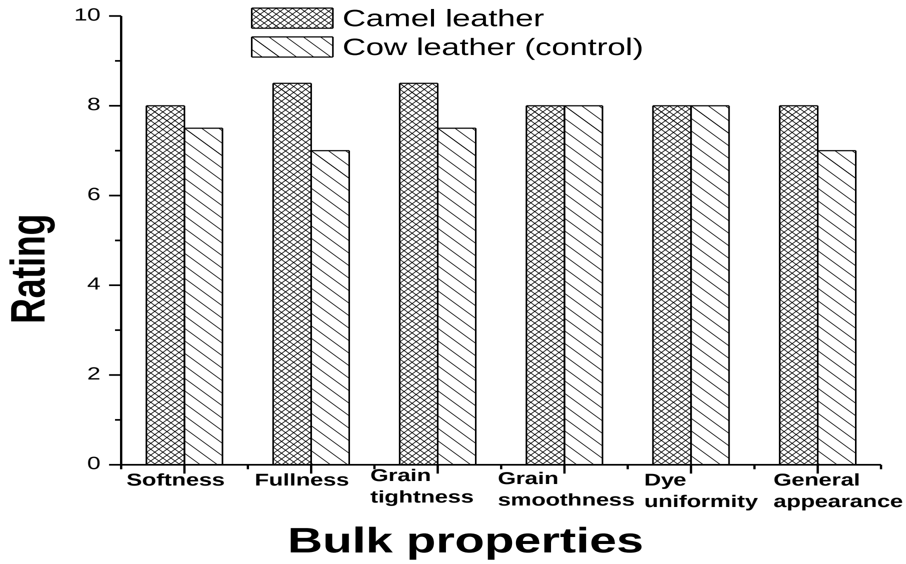


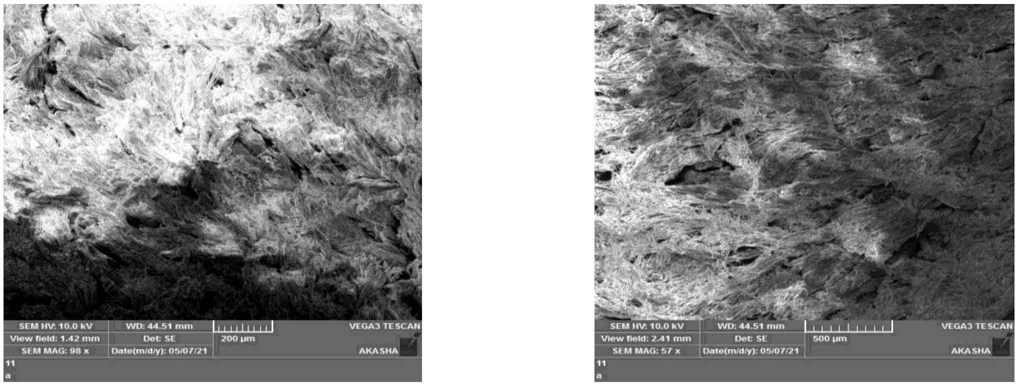
Figure 4.3 Graphical representation of organoleptic properties of the Experimental and control leather

Table 4.2 Physical strength Characteristic of experimental and control crust leathers

Parameter	Experimental camel leather	Control Cow leather	BIS standards
Tensile strength (Kg/cm^2)	263±2	215±3	200
Elongation at break (%)	63±1.6	58±1.6	40-65
Tear strength (Kg/cm)	66±1.7	54±0.7	30
Load at grain crack (kg)	41±1.5	36±1.5	20
Distention at grain crack (mm)	13±0.5	12±07	7

4.5 Scanning Electron Microscopic Analysis of Leather Samples

Scanning electron micrograph of crust samples from both experimental (Figure 4.4 A) and control leathers (Figure 4.4 B) showing well separated and opened up fibres. However, more compact and coated fibres are seen in the case of experimental leather (camel) and it is possess better fullness. The fibre compactness seems more clear and resembles the cow hides. This feature of the camel leather explains that the raw material is suitable for the manufacture of shoe upper leathers.



A **B**

Figure 4.4 Scanning electron microphotograph of chrome tanned camel leather(**A**) and chrome tanned cow leather (**B**)

4.6 Chemical Analysis of the crust leather

The chemical analysis values of experimental crust leathers and control are given in Table 4.3. The chemical analysis data for the experimental leathers is comparable to that of control leathers.

Table 4.3 Chemical Analysis of Experimental and Control Crust Leathers

Parameter	**Experimental Camel Leather**	**Control Cow Leather**
Moisture %	14	12
Total ash content %	6.4	6.2
Fats and oils %	4.8	4.3
Chrome oxide (Cr_2O_3)	3.8	3.5

Chapter Five

Conclusions and Recommendations

5.1 Conclusions

In Sudan many alternative animals where the hides and skins can be obtained from them and could be processed into leathers. From these alternative animals, camel was considered as best alternative due to its higher off-take rate compared to the rest of the others. The main source of raw material for the Sudan leather sector comes from sheep, goat and cattle. Camel hides are being considered as an additional source of raw material for the tanning industries. In the present study, camel hides were used for manufacture of upper crust leathers and compare with conventional cow hides. The physical and chemical analysis indicates that the experimental leathers are comparable to control leathers in terms of all the properties. The bulk properties for the experimental leathers are better than control leathers. Scanning electron microscopic analysis for both control and experimental leather samples show good separation of fiber bundles.

The chemical and physical characteristics of the experimental camel leather revealed that the camel hide raw material was suitable for making of shoe upper leather, leather good and belting leather. In Sudan camel was considered as best alternative animal to conventional raw materials such as sheep, goat and cattle due to its higher off take rate.

5.2 Recommendations

- Facilitate the development of improved husbandry practices by making good relationship to the Line Ministries Africa/LLPI, UNIDO, FAO, Sudan Bureau of Standards, Specialized and academic Institutions; Leather Chamber.
- The Sudanese government should provide a system can rear camels for the purpose of meat and milk production.
- Facilitate the development of an efficient camel hides production system by making good relationship to the Line Ministries Africa/LLPI, UNIDO, FAO, Sudan Bureau of Standards, Specialized and academic Institutions; Leather Chamber.
- Raise awareness on the importance of camel hides among the value chain players and processing the camel hides for different applications.
- Sudan government should also facilitate the opportunity in the marketing of the camel products

- Facilitate the development of an efficient Hides and Skins preservation storage and transport system by making good relationship to the Line Ministries Africa/LLPI, UNIDO, FAO, Sudan Bureau of Standards, Specialized and academic Institutions; Leather Chamber.
- Train Slaughter house foremen/supervisors for enforcing total quality management in the flaying process
- Train flayers on proper flaying techniques.
- Train collectors and slaughter house owners and workers on proper preservation techniques.
- Creation of educated generation of workers with basic employable skills according to a recognized functional map and skills standards.
- Develop policies aimed at promoting value addition in the leather value chain

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Figure 5.1 Arab camel (Male)

Figure 5.2 Rashaidi camel (Female)

Figure 5.3 Anafi camel

Figure 5.4 Bishari camel