BIOLOGICAL FACTORS INFLUENCING THE NATURE OF GOAT SKINS AND LEATHER

A thesis submitted for the degree of Master of Philosophy
University of Leicester

PHILIPPA STOSIC
BSc. Hons., ASLTC.

May 1994

Acknowledgement

The author wishes to thank Dr. Geoff Attenburrow (British School of Leather Technology, Nene College) and Prof. Mike Blandamer (University of Leicester) for their help as supervisors and David Silverside (Natural Resources Institute) for his patience during this project. Thanks are also due to Malcolm Pickles for his help and guidance on practical leather matters and to Rod without whom it would never have been finished. The work was financed by the Natural Resources Institute under their hide improvement scheme. The raw materials for this project were supplied through collaboration with Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA), Sobral, and the Nucleo Regional de Processamento e Pesquisa em Couros e Tanantes (PROCURT) of the Federal University of Paraiba, Campina Grande, N.E.Brazil.

This thesis describes original work by Philippa Stosic which was completed mainly during the period of registration.

Abstract

The effect of a goat's sex, age, slaughter weight and nutrition on its skin and leather quality were investigated through chemical, biochemical, histological and hydrothermal analyses of dried skins, and physical testing of leathers. This work formed part of a larger project sponsored by the Natural Resources Institute, who provided the Brazilian goat skin raw materials.

The basic chemical constituents (moisture, fat and nitrogen) of skins were influenced by both the age and sex of the animal. Their effect on the biochemical components (GAG and collagen contents) were less defined and probably a reflection of the early maturing nature of these components in the skin. Under different nutritional conditions only the fat content of skins varied significantly, being higher in skins of animals on a high plane of nutrition. The GAG contents of low nutritional skins were slightly higher than the corresponding high nutritional skins. A positive correlation between the slaughter weight of animals and GAG content of the skins was found.

The weight, age, sex and nutritional conditions all influenced the thickness of the skin. The main influences were the slaughter weight (linked to age and nutrition) and the sex of the animal. The increase in thickness predominantly occurred in the corium layer of the skin. Differences in corium fibre structure, in particular the compactness and angle of weave, were related to skin thickness.

Physical properties of the leathers were directly related to the thickness of the skin (and weight), grain to corium ratios and corium collagen structure. The leathers became stronger and gave lower distentions with increasing age and nutritional stress. The physical properties of the leathers were also linked to the sex of the animal. The strongest leathers were obtained from male animals. Softness of leathers was influenced by the sex of the animal and slaughter weight.

CONTENTS **Page**

CONTENTS cont. **Page**

CONTENTS cont. **Page**

CONTENTS cont. **Page**

CONTENTS cont. **Page**

List of Tables

List of Figures

Chapter 1 Introduction

1.1 General Introduction.

The goat is one of the most universal of animals, both in terms of its distribution and exploitation. It can be found over a wider geographical area than any other domesticated ruminant, mainly due to its unequalled ability to adapt and even thrive in the many and varied conditions it encounters (Epstein (1965)). Goats make their greatest contribution in the tropical and arid regions of the world where they seem to be better adapted to the environmental extremes, especially compared with the "wooled" sheep which have now displaced most of the "hair" breeds in all but the humid areas (Devendra & Coop (1982)). The ability to conserve water, travel well and a certain resistance to disease and parasitism all play a part in the distribution of the animal (Rae (1982)).

Nearly 77% of the goat population is concentrated in the tropical and arid zones of the world (Raun (1982)). Devendra & Coop (1982) indicate that nearly 80% of the worlds goats are to be found within the 0-40°N latitude band compared to only 40% of the world's sheep. Taken as a whole sheep are numerically more important in tropical regions, however goats predominate in the more humid areas.

Although goat rearing is a world wide activity, it is primarily in the developed countries that goats are kept commercially, largely for their luxury fibre and dairy production. The meat is very much a by-product of these ventures. The only goat products to enter the international arena in any great quantity are the skins. Naturally as the majority of the goat livestock are held in the less developed countries, these countries produce virtually all of the world's goatskin supplies (table (1)). Traditionally there have always been countries supplying, while others import the skins. The major importing markets are Europe, principally Italy and Spain and USA. The USA accounted for 63% of world imports of goat and kidskins in 1991 (F.A.O.(1992b)). Now, however more and more of the primary producing countries are also beginning to process their own skins, to increase their value and to supply their own burgeoning leather industries. This processing can be as basic as a simple rough tannage through to the export of fully finished leather and goods (Holst (1986)).

Whether the producing country sells cured, semi-processed or even fully finished work, goatskins represent a readily available resource for many of the developing nations. By capitalising on a valuable raw material, which otherwise is a by-product of other production systems, they can provide a saleable, sought after commodity with considerable foreign trade earnings (table (1)).

Table 1 World goat populations, goatskin production, imports and exports for 1991. Figures were taken from FAO estimates, parentheses indicate the regional percentages of the world values.

REGION	GOAT POPULATION† 10^6 (%)	GOATSKIN PRODUCTION‡ 10^3t (%)	GOATSKIN IMPORTS‡ 10^3t (%)	GOATSKIN EXPORTS‡	
				10^3t (%)	10^6US$ (%)
DEVELOPED NATIONS*	32 (5)	11 (7)	21 (76)	5 (20)	27 (23)
DEVELOPING NATIONS**	562 (95)	157 (93)	7 (23)	22 (80)	94 (77)
WORLD	594	168	28	27	121

† - F.A.O. (1992a)

‡ - F.A.O. (1992b)

* - N. America (Canada & USA), W. Europe, Oceania (Australia & New Zealand), Israel, Japan, S. Africa and E.Europe (Albania, Bulgaria, Czechoslovakia, Hungary, Poland, Rumania and USSR).

** - Developing Africa, Latin America, Near & Far East, Asian CPE (China, N. Korea, Kampuchea, Mongolia & Viet-Nam) and Oceania.

Many countries, for example Egypt, Morocco and Tanzania have imposed export bans on raw hides and skins and on leather raw materials in an attempt to prevent the drain on supplies to their own industries. This has not always had a beneficial effect on the leather produced. Few incentives are given by the monopolistic buying organisations to the farmers, who have sometimes received as little as 10-20% of world prices for their

product (Anon (1987)). Consequently the quality and quantity of hides and skins have fallen. Estimates of up to US$ 800 million per annum have been suggested as the economic losses due to damage and non-recovered hides and skins in Africa alone; this is almost ten times their annual export value. US$ 2.9 billion has been estimated as the losses in not processing all the hides and skins to leather products (UNIDO (1987)).

Goat skins have a very tight fibre network compared with sheep and cattle (figure (1)), producing resilient, strong and more durable leathers with the ability to recover its shape after deformation. Its leather qualities are different from those produced from other animals and as such are suited to different end purposes. The quality of the grain can be particularly important especially in such leathers as "glazed kid". Skins with coarser grains, or with grain defects are still in demand for suedes, velours and corrected grain leathers. Because of its particularly tight fibre pattern goatskins produce a fine, soft suede suitable for many footwear and clothing applications (Devendra & Burns (1970)). The skins form the basis of many of the top quality products of the leather industry. These include velours, suedes and chamois for clothing; chevreau, saffin, morocco and glazed kid for gloving, book-binding and other fancy leathergoods (Gall (1981)). Approximately 60-70% of the world goatskin leather is used in the manufacture of shoes, 20% for garments and 10-20% on other items (Holst (1986)).

Goatskins are also used in many traditional or craft industries in the countries of origin for such items as footwear, clothing, bedding, scabbards, water bags and other household utensils (Josserand & Ariza-Nino (1982); Martin (1982); Wilson (1982); Okello & Obwolo (1985); Devendra & McLeroy (1982)), although these traditional applications are declining as the use of plastic and manufactured goods continues to spread (Barrett (1985)).

i ii

iii iv

Figure 1 Cross sections of leathers made from (i) goat, (ii) hair sheep, (iii) wool sheep and (iv) cattle hides (x50).

1.2. Factors Affecting Skin and Leather Quality.

The value of goatskins is ultimately governed by their quality, although market factors do also play a part. Any factor, therefore, that affects or influences this quality, whether positive or negative, will be important to both the producer and the consumer. These "quality affectors" fall into four areas, damage to the skin occurring before (Gbolagunte *et al* (1987); Green (1956); Haines (1978); Halligan & Johnstone (1992); Ibrahim & Abu-Samra (1987); Venkatestan (1977)) and after slaughter (Cook *et al* (1990); Gratacos *et al* (1989); Haines (1978)) during preservation (curing) (Hopkins *et al* (1973); Barlow (1976); Haines (1984); Barrett (1986)), plus alterations to the basic nature of the skin itself. The first three of these areas have been extensively investigated over the years, and the principles developed from these investigations hold true for most animal skins. The structure of the skin and the biological factors influencing it are, however, more species orientated.

In recent years considerable work has been carried out into biological factors and their influence on skin characteristics and quality. This research has principally been carried out in developed countries and on species relevant to these areas i.e. cattle and sheep, little of the work so far has been specific to goats. It has been shown that in these species skin, and subsequent leather, quality can be influenced by such factors as the sex (Clark (1986)), the age (Bowes *et al* (1967); Russell *et al* (1977); Passman & Clark (1982), the live weight of the animal (Haines (1981); Russell *et al* (1980)), the breed (Olivannan *et al* (1977); Haines (1981); Passman (1981)) as well as by feeding and environmental conditions (Clark (1986); Bowes & Raistrick (1966); Russell *et al* (1980); Bruyn *et al* (1987)).

Although little of the work that has been carried out has been specific to goats, there have been a few projects aimed at improving the quality of goat skins (Devendra & Burns (1970)). These include the attempts of the Nigerian government to prevent the deterioration of the Red Sokoto (Maradi) breeds by banning its crossing with other goats. While in Niger more active measures such as the castration of inferior males

have been taken, with the distribution of Maradi males to outlying districts (Robinet (1973); Hauesser (1975) quoted in Mason (1981)).

Burns (1965), undertook an histological examination of some of the Nigerian breeds to assess their leather making qualities. He suggested that low overall hair density could be associated with the production of good quality skins. This is borne out by studies undertaken in Australia where the fineness of the grain appeared to be related to the density of the primary hair follicles (Allan *et al* (1987); Holst *et al* (1987); (1989)).

1.3. Development and Improvement Schemes.

The production system operated by the livestock owner determines both the numbers and types of animals kept (table (2)). The structure of the herd reflects the production objectives and hence the chosen production system of the owner.

In table (3) it is seen that where milk is the primary objective of production the herd is naturally predominantly female. Where meat is also a requirement the numbers of females, as a whole, is reduced. When, for example in the case of the Masai, fat males are sought (for social reasons), then the numbers of entire and castrated males increases. However, the proportions of breeding females remains little changed for any of the systems. This variation in the demography of the herds will in turn reflect the type and ages of the animals sold and slaughtered. In most existing systems the majority of the animals slaughtered will be young and culled males, along with the old and barren females.

Table 2 Management schemes used in goat production.

TYPE OF PRODUCTION	LABOUR INPUT	HERD SIZE & PRODUCTION AIM.
TETHERING	LIMITED	Usually single or family goats producing meat & milk for household use.
EXTENSIVE	LOW	Ranges from small family herds to large nomadic flocks, mainly for meat production (100-1000 head).
INTEGRATED	INTERMEDIATE	Medium to large herds (50-500), for meat & milk.
INTENSIVE	HIGH	Medium sized commercial herds (50-250), for milk production.

Table 3 Management objectives related to the herd structure, expressed as a percentage of all animals. Taken from Wilson *et al* (1985).

REGION/ETHNIC GROUP	PRODUCTION AIM	MALES		FEMALES	
		Total	Castrates	Total	Breeding
ETHIOPIA/AFAR	MILK	3.3	0.0	96.7	65.5
NIGER/TAMSHEQ	MILK	14.1	0.0	85.9	66.7
SUDAN/BUGGARA	MEAT & MILK	23.6	0.0	76.4	66.7
KENYA/MASAI	MEAT (FAT) & MILK	33.8	10.3	66.2	48.2

The basic aim of improvement and development schemes has been to increase food production from the animal, whether on an individual basis or through increased numbers. Skins and other by-products do not usually form part of the considerations of such schemes. The goat development schemes being run in Fiji, for example, were set up with the aim of achieving self-sufficiency in goat meat production for the islands thus saving hard currency on imports. During the period 1976-1982 the level of self-sufficiency increased from 46% to 68%, achieved through assisting the farmers to increase their flocks and to improve their productivity in terms of land usage, labour and livestock (Hussain *et al* (1983)).

As improvement schemes are employed so the nature of the goats being killed will also change. Where intensification of the production system occurs, the age of the slaughtered animals will be seen to decrease. Housed or penned animals under regulated nutritional regimes will have a faster growth rate and attain a larger mature size, than those left to forage and graze in the extensive systems. The animals are also, by virtue of being housed or attended, open to less mechanical damage to the skin through scratches and wounding. Diseases and parasitic infections can also be

more readily detected and dealt with, although intensive systems can also increase disease risks (Upton (1985)).

Many improvement schemes involve the introduction of exotic or improver breeds to upgrade meat and milk production of the native animals. Most of these improver breeds are larger than the indigenous animals. Thus through their introduction into the breeding stock larger, faster maturing animals are likely to be produced. Growth rates can be improved by crossbreeding with males of a larger breed without affecting feed rates for maintaining the animals. For example, Boer males crossed with indigenous small East African goats in Kenya produced kids that reached an average weight of 25 kg at half the age of the indigenous animals (Haas & Chemitei (1973)).

Where the animals are kept under extensive free range systems very few adult males are required, a small number being able to service the whole village flock. When the animals become confined under more intensive systems so the proportions of adult stud males in the village will also be increased, unless there are "borrowing" arrangements (Upton (1985)).

It is only in recent years that goats have been "taken up" and used in many of the development and improvement programmes of the developing countries. Their development has been constrained to a great extent by the lack of published knowledge and information regarding such matters as breeds, types, their performances and potentialities (Devendra & McLeroy (1982)). Now as the traditional goat production systems are being improved or new schemes introduced, so the by-product, the skin, will inevitably be affected. To what extent or in what way the skin will be altered is not always certain. However the quality of the goatskin and the leather produced from it are dependent upon the management, husbandry and genetic factors as well as by the environment (Holst (1986)), all of which will in some way be altered, improved or otherwise, by development schemes. The skins are never the primary concern of the livestock owner.

1.4. Project Aims.

This project set out to characterise and assess the influence that specific biological factors, likely to be altered in improvement schemes, have on the chemical, structural and physical nature of goatskins and the quality of the leather produced from them. The work reported here investigated the effect the sex, age and slaughter weight of Brazilian goats had on their skin and leather qualities as well as the effect of high and low nutritional regimes. This work formed part of a larger project sponsored by the Natural Resources Institute, which also investigated the effects of breed.

The information gained from this work is important as the majority of the developing goat keeping countries are either exporting the skins or utilising most of their rawstock in their own expanding leather industries. Thus any "improvement" or alteration in the way goats are reared to produce meat or milk may have significant economic repercussions in the leather sector and possible foreign trade earnings.

Chapter 2 Goat Skin Raw Materials

2. The Overall Project Scheme.

The project was split into two phases dealing with different biological parameters appertaining to the live animal. The goat skin raw materials for the project were supplied by the Natural Resources Institute (NRI) through collaboration with Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA), Sobral, and the Nucleo Regional de Processamento e Pesquisa em Couros e Tanantes (PROCURT) of the Federal University of Paraiba, Campina Grande, N.E.Brazil. The selection, slaughter and feeding of the animals as well as the animal data collection were outside the control of the author.

Phase I of the project was designed to investigate the effect the sex, age and slaughter weight of the animal on the nature of its skin and subsequent leather. The goat skins provided were from the general population of goats in N.E. Brazil and the results were intended to act as "baseline data" for Phase II which investigated the role of animal nutrition and Phase III, carried out by Wang (1992), which looked at breed effects on skin quality.

2.1. Phase I - Sex, Age and Slaughter Weight Effects.

84 goats, from the general goat population, were incorporated into the project from 10 slaughter houses in the Pernabuco State of N.E.Brazil during the summer of 1987 (figure 2). The animals were categorised by the suppliers according to the following parameters:

i. 3 sex groups - Male, Female and Castrate.

ii. 4 age groups - 0 - up to 15 months,
2 - 15 to 21 months,
4 - 22 to 26 months,
6 - over 26 months.

iii. 4 slaughter weights groups - 1 - up to 9.9 kg,
2 - 10 to 14.9 kg,

3 - 15 to 19.9 kg,

4 - 20 kg and over.

Region		**Collection Points**	
A	Catolé Do Rocha	1	Taperoá
B	Sertão Paraibano	2	Assunção
C	Curimatau	3	Cabaceiras
D	Piemonte Da Borborema	4	Boa Vista
E	Litoral Paraibano	5	Sumé
F	Sertão De Cajazeiras	6	Serra Branca
G	Depressão Do Alto Piranhas	7	Soledade
H	Cariris Velhos	8	Cubati
I	Agreste Da Borborema	9	São Joao Do cariri
J	Brejo Paraibano	10	Juàzerinho
K	Agro-Pastoril Do Baixo Paraiba		
L	Serra Do Teixeira		

Figure 2 Map of N.E. Brazil indicating sample sites for collection of Phase I goat skins.

The age of the animals was estimated from the numbers of permanent incisor teeth i.e. 0, 2, 4 or 6 (Kirton (1970)). The slaughter weights of the animals were based on the carcase weights, which included the head and red offal (the 1/5th quarter), and the uncleaned skin weight. Curing, in the form of air drying, took place in controlled drying sheds at 25 ± 5°C, 36% relative humidity (RH) until the skins had a moisture content of about 10 - 15%. Data on the carcase weights, cleaned and uncleaned green skin weights as well as the moisture content and weight of the dried skins were obtained by EMBRAPA and PROCURT in Brazil before the skins were cured.

Table (4) shows the numbers of goat skins analysed in 12 categories according to the animals sex and age at slaughter. Originally it was envisaged that data on 10 animals would be provided in each of the 12 experimental "cells", but this was not the case during the allotted collection period. These numbers are a reflection of the relative types of production systems operating and the resulting types of goats being slaughtered in the area i.e. mainly young males/castrates and culled females. As stated the animals were taken from the general population of animals being slaughtered and were all classified as Sem Raça Definida (SRD). It is estimated that these SRD goats "without defined breed" make up 60% of the goat population in Brazil, the other 40% of the population either have been improved by crossing with pure breeds (23%), mainly Anglo Nubian, or are of a defined breed (17%) (Buvinuin *et al* (1980)).

The 84 goat skins were also re-categorised taking account of the animals sex and weight at slaughter. The numbers of animals in these groupings are shown in table (5).

Table 4 Numbers of goat skins collected and used in Phase I: Sex and age groupings.

SEX	AGE GROUP			
	0 (→15m)	2 (15-21m)	4 (22-26m)	6 (27+m)
MALE	10	8	4	2
CASTRATE	10	10	1	8
FEMALE	4	10	7	10

(m - months)

Table 5 Numbers of goat skins collected and used in Phase I: Sex and slaughter weight groupings.

SEX	SLAUGHTER WEIGHT GROUP			
	1 (→9.9 kg)	2 (10-14.9 kg)	3 (15-19.9 kg)	4 (20+kg)
MALE	11	8	5	-
CASTRATE	11	8	7	3
FEMALE	5	15	11	-

2.2. Phase II - Nutritional Effects.

The goat skins from 59 animals involved in nutritional trials taking place at Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA) Sobral, Ceará, N.E.Brazil during the autumn of 1987 formed the raw material for this part of the project. The animals were all SRD castrated males, about 6 months old at the start of the experiment and chosen from the general population of goats; i.e. of no recognised breed.

The animals had been apportioned into 6 treatment groups designed to investigate the effects of 2 nutritional regimes (high and low) on experimental goats infected with varying doses (high and low) of the intestinal worm *Haemonchus contortus*. One low and one high nutrition group had not been infected and acted as control groups. A summary of the various treatment groups is given in table (6).

2.2.1. Nutritional Burdens.

2.2.1.1. Experimental Feeding Rates.

The amount of food given by the group in Brazil to the animals each day was based on the animals' live weight. For example a 13 kg animal received 166 g of feed concentrate/day in the low nutrition (LN) groups and 332 g of concentrate/day in the high nutrition (HN) groups i.e. twice the amount given to the LN group. The amounts of feed given to the animals had been adjusted weekly according to the weight gained.

2.2.1.2. Animal Nutritional Requirements.

An animal's requirement for energy is referred to as its metabolisable energy (ME) requirement. The ME required by an animal per day depends on such factors as its activity, the environmental temperature, whether it is still actively growing or producing milk (Mowlem (1988)). The energy requirement of an animal is also a function of its metabolic body size, rather than its live weight. The unit of metabolic body for a goat is live weight in kg to the power of 0.75.

If the ME requirement for goats is taken as 0.5 MJ/kg$^{0.75}$ per day[2] then an animal with 13 kg body weight would require 3.4 MJ ME/day from its daily intake of feed. The feed concentrate given to the goats in the nutritional trial consisted of 78% maize meal and 20% soya bean bran and 2% salt (Figueiredo (1990)). From table (7) it can be seen that the concentrate had a estimated total ME value of 9.6 MJ ME/kg of feed. This meant that when the 166 g of feed was given by the trial supervisors in Brazil to each of the goats on the low nutritional scheme they would obtain approximately 1.6 MJ ME. This ration of food would therefore only supply the animal with about half its daily maintenance requirement. The high nutrition groups, which were receiving double this ration, would have in fact been receiving approximating the ME requirement. It should be noted that these animals were still probably receiving a higher daily nutritional intake than the extensively reared or range animals used in Phase I.

[2] BAPTIST & GALL (1992) quote the maintenance requirements for Kenyan Galla goats as:

0.50 MJ ME/kg$^{0.75}$ - birth to 1/4 adult body weight
0.48 MJ ME/kg$^{0.75}$ - 1/4 to 1/2 adult body weight
0.47 MJ ME/kg$^{0.75}$ - 1/2 to 3/4 adult body weight
0.46 MJ ME/kg$^{0.75}$ - 3/4 to 1/1 adult body weight
0.45 MJ ME/kg$^{0.75}$ - at maturity.

MOWLEM (1988) quotes 0.5 MJ ME/kg$^{0.75}$ for the maintenance of UK dairy goats rising to 0.7 MJ ME/kg$^{0.75}$ for the last month of a pregnancy, maintenance + 5MJ/kg of milk is required for lactating goats.

Table 6 Summary of EMBRAPA nutritional experimental groups and goat numbers.

GROUP	GOAT NUMBERS	TREATMENT
LN	6	Control group: maintained on a Low level of Nutrition.
HN	7	Control group: maintained on a High level of Nutrition.
LNLW	11	Low Nutritional feeding with a Low Worm burden.
LNHW	11	Low Nutritional feeding with a High Worm burden.
HNLW	11	High Nutritional feeding with a Low Worm burden.
HNHW	13	High Nutritional feeding with a High Worm burden.

Table 7 Estimated energy value of nutritional trial feed concentrate.

FEED CONSTITUENT	DRY MATTER (DM) %	ME MJ / kgDM	PERCENTAGE IN FEED	ME / kg FEED
MAIZE MEAL	90	11.7	78	8.2
SOYABEAN BRAN	90	7.5	20	1.4
SALT	-	-	2	-
TOTAL	90	19.2	100	9.6

(ME - metabolisable energy)

2.2.2. Parasitic Burdens.

2.2.2.1. Experimental Dosages.

The low worm (LW) burden group of animals were orally infected by EMBRAPA in Brazil fortnightly with 500 L3 stage *Haemonchus contortus* larvae. Those animals classified having had high worm (HW) burden had been given 2000 L3 stage larvae every two weeks (Figueiredo (1990)).

2.2.2.2. Parasite Life Cycle.

The basic life cycle of a nematode worm involves the larvae undergoing a series four moults during which the cuticle is shed. The successive larvae stages are described as L_1, L_2, L_3, L_4 and L_5. After hatching the free-living (on pasture) larvae undergo two moults to reach the infective L_3 stage. After infection the larvae undergoes two more moults to reach the L_5 or immature adult parasite, just before the final moult they develop the piercing lancet which allows them to obtain blood from the abomasum lining (Urquhart *et al* (1992)).

2.2.2.3. Pathogenic Effects of Infection.

Small ruminants are extremely susceptible to a wide range of nematode (round worm) endoparasites (Gracey & Collins (1992)). Considerable nutritional burdens have been demonstrated to animals even with moderate levels of infection (Coop *et al* (1982); McAnulty *et al* (1982); Brunsdon & Vlassof (1986)). Endoparasites have a preference for particular sites in the alimentary tracts of their hosts (table (8)). The type of damage caused to the host animal also varies with the species of nematode.

H. contortus bores into the abomasum's mucous membrane and feeds off the resulting blood flow. The pathogenic effects of *H. contortus* result from the hosts inability to compensate for the blood loss. An infestation of 3000 worms can deplete an animal of approximately 0.6 litres of blood in a week (Gracey & Collins (1992)). Under good nutritional circumstances and with low levels of infection (up to 500 worms) there may not be any measurable signs of illness. However if the animal is stressed through for example poor nutrition or heavy worm burdens then a progressive anaemia may lead

rapidly to death (Symons (1985)). Repair of the damage caused by the parasite to the intestinal tissue, with the increased mucus and plasma secretions, as part of the host immune response, increases the body protein synthesis and can lead to an induced protein deficiency (Georgi & Georgi (1990)). *H. contortus* infections can cause a depression of the digestibility and absorption of protein, calcium and phosphorus (Mönnig (1950)).

All the animals were slaughtered between the ages of 9 and 11 months (corresponding to the Phase I age group 0). A summary of the goat numbers according to their treatment and slaughter weight groups (as previously described in Phase I) is given in table (9). The animals were all hand flayed, the skins trimmed, cleaned and dried in Brazil under the same conditions as previously described in Phase I.

Table 8 Location of endoparasites in sheep (taken from Sykes *et al* (1992)).

SITE	SPECIES
ABOMASUM	*Haemonchus contortus* *Ostertagia cirumcincta* *Trichostrongylus axei*
DUODENUM & PROXIMAL SMALL INTESTINE	*Nematodirus battus* *Trichostrongylus colubriformis* *Strongyloides papillosus*
CAECUM, COLON & DISTAL ILEUM	*Oesophagostomum venulosum* *Trichuris ovis*

Table 9 Summary of goat numbers in Phase II slaughter weight and treatment groups.

TREATMENT GROUPS	SLAUGHTER WEIGHT GROUPS			
	1 (→9.9 kg)	2 (10-14.9 kg)	3 (15-19.9 kg)	4 (20+kg)
LN	-	-	3	3
LNLW	-	3	7	1
LNHW	-	4	7	-
HN	-	-	3	4
HNLW	-	-	5	6
HNHW	-	2	5	6

2.3. Skin Analysis.

Dried skins were received from the two Brazilian establishments and the investigations reported in this thesis were carried out at the British School of Leather Technology (BSLT), Nene College, Northampton.

A complete evaluation of the skins' characteristics was carried out for each of the groups in each phase of the project. This involved chemical, biochemical, histological and physical analysis of the rawstock and subsequent processed leather. A summary of the procedures carried out is given in table (10). The processing method used to make leather from dried skins is given in Appendix I. Results from Phases I and II goat skin analyses and the data provided from Brazil are given in Appendices II and III respectively. Statistical methods used to analyse experimental data are given in Appendix IV along with results of the analyses.

Table 10 Summary of procedures used in the analysis of trial skins.

SUBSTRATE	ANALYSIS	PROCEDURE
Dried Skin	Chemical	- % Moisture - % Fat - % Nitrogen
	Biochemical	- % Collagen - % Glycosaminoglycan (GAG)
	Histological	- Total skin thickness - Grain thickness - Corium thickness - Hair follicle depth - Assessment of collagen fibre structure.
	Physical	- Isometric tension testing (IMT)
Crust Leather	Chemical	- Chrome content
	Physical	- Tensile strength - Grain crack and burst - Softness

Chapter 3 Experimental Procedures

3. Experimental Procedures.

3.1. Chemical and Biochemical Analysis of Dried Skins. The sampling position for the chemical and biochemical analysis of the dried skins is shown in figure 3. The hair was removed by clipping close to the grain surface and the skin samples were finely chopped and mixed before the analysis was undertaken. All analyses were carried out in duplicate unless otherwise stated. Analysis was carried out on each of the skins in the various group categories (Chapter 2) and mean values were then calculated for each of these groups.

Figure 3 Schematic diagram of dried goat skin showing test sampling positions

3.1.1. Moisture Content.

The moisture content of 5 g samples of the air dried, chopped skins were determined using method (3) of BS1309 (1974) standard method. The moisture content was taken to be the percentage weight lost by the skin samples when dried at 102 ± 2°C to constant weight ie. samples were re-dried if the reduction in weight was more than 0.1% of its original weight. The total drying time was not allowed to exceed eight hours.

3.1.2. Fat Content.

The fat contents of the moisture free samples (section 3.1.1.) were determined using method (4) of BS1309 (1974) standard Soxhlet extraction method. The fat content was taken to be the percentage weight of substances extracted from the samples using the solvent dichloromethane. The process allowed for at least 30 exchanges of solvent, taking approximately 5 hours. After distilling the solvent from the flask the extracted materials were dried at 102 ± 2°C to constant weight. Samples were re-dried if the reduction in weight was more than 0.1% of its original weight. The total drying time was not allowed to exceed eight hours.

3.1.3. Nitrogen Content.

The nitrogen content of 1 g moisture free, fat free samples of skin (section 3.1.2.) were determined using method (7) of BS1309 (1974) standard method, which is a modified Kjeldahl method.

The determination of the total-nitrogen in the skin samples involved two distinct stages:

i. digestion with acid to convert nitrogen to ammonia,
ii. the determination of ammonia in the digest.

The skin samples were first oxidised in hot, 0.1 M nitrogen free sulphuric acid catalysed by a mixture of anhydrous sodium sulphate, anhydrous copper (II) sulphate and selenium powder (in a ratio of 20:10:1 respectively). The selenium and copper (II) sulphate were the catalysts of the oxidation of the organic compounds with the sulphuric acid, the neutral sodium salt increased the boiling point of the acid and thus the temperature at which the oxidation reaction took place.

After the oxidation reaction was judged to be complete (the mixture being heated for one hour after all the carbon particles had cleared leaving a green solution), the contents of the flask were cooled, diluted with water and made basic with 30%($^{w}/_{v}$) sodium hydroxide solution to liberate ammonia. A process of steam distillation carried the liberated ammonia to the receiving flask of excess saturated boric acid and indicator (0.1% methyl red and 0.1% methylene blue in 95%($^{v}/_{v}$) ethanol). After 10 minutes the distillate was tested to make sure all the ammonia had been distilled (with red litmus paper). The contents were then made up to 500 ml with water and 25 ml aliquots titrated against a standard 0.01 M hydrochloric acid (HCl) solution.

The nitrogen content (N) was calculated as a percentage of the original skin weight as follows:

$$N / \% = \frac{\text{titre / ml} \times 0.01\text{ M HCl} \times 0.014 \times 20}{\text{weight of sample / g}} \times 100$$

Blanks were determined substituting 1 g of glucose for skin samples.

3.1.4. Collagen Content.

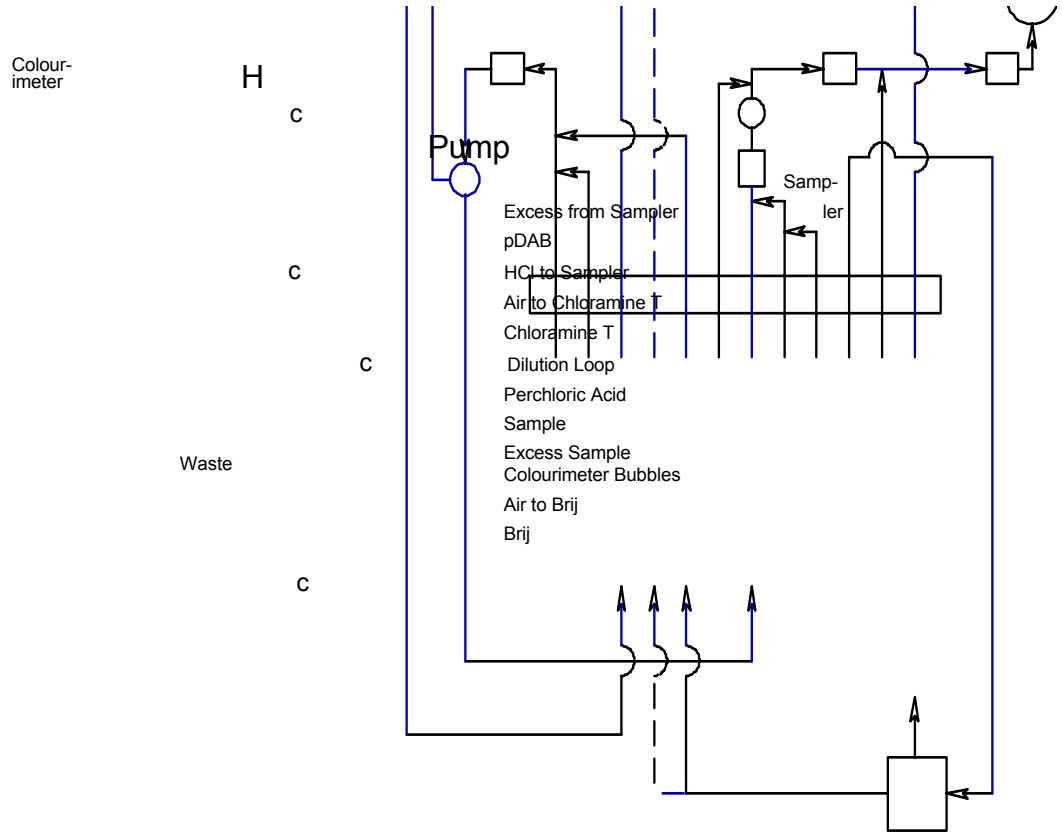
The collagen contents of 1 g moisture free, fat free samples of skin (section 3.1.2.) were calculated by determining their hydroxyproline contents (SLC(21) 1966).

The determination of hydroxyproline in the skin samples involved hydrolysis of the protein to liberate the amino acid from peptide linkage, oxidation with Chloramine T and reaction of this product with p-dimethylaminobenzaldehyde (pDAB) to give a pink chromophore (Neumann & Logan (1950)).

1 ml of the papain skin digest (see section 3.1.5.) was added to an equal volume of 6 M hydrochloric acid (HCl) in a Pyrex culture tube with a Teflon-lined screw cap for 20-24 hours at 105 ± 2°C. The samples were then cooled, diluted with water to make 5% HCl and filtered through glass wool. Samples were diluted at this stage, if necessary, with 5% HCl to obtain approximately 800 μg/ml of original skin sample.

The Technicon Autoanalyser system (figure 4) was used for the determination of hydroxyproline, in which the sampling, addition of reagents, mixing, filtering, heating and absorbance measurement (at 562 nm) were automated. Standard curves using 25, 50, 75, 100, 125, 150 and 175 μg/ml hydroxyproline solutions were produced for each sampling run. Samples were examined in duplicate and run through the analyser at least three times.

The hydroxyproline content (mg/ml) was calculated for each sample using the standard curves and taking into account all dilution steps. The collagen content (mg/ml) of the samples were then calculated using 6.99 as the conversion factor (i.e. collagen contains 14.3% hydroxyproline (Bowes (1959)). Finally the collagen content as a percentage of the original dry, fat free skin weight was calculated.



c - Reaction Coil
H - Heating Coil

Figure 4 Flow diagram of the Technicon Autoanalyser used for hydroxyproline analysis of skin samples.

3.1.5. Glycosaminoglycan (GAG) Content.

The GAG content of 1 g moisture free, fat free samples of skin (section 3.1.2.) were calculated by determining the dermatan sulphate and hyaluronic acid levels as a percentage of the collagen present. The procedure involved an enzymic digestion to solubilise the collagenous parts of the skin sample and the quantification of the GAGs by measuring the absorbance of the stained digest (Alexander & Kemp (1984): Alexander *et al* (1986)).

The skin samples were digested in Pyrex culture tubes with Teflon-lined screw caps in a 0.1 M sodium phosphate buffer and papain solution (pH 6.4) for 16-32 hours at 60-70°C. The buffer solution contained 0.3 M sodium chloride to prevent the precipitation of papain complexes, 0.005 M cysteine hydrochloride which is a papain activator and 0.01 M disodium ethlenediaminetetra-acetic acid (EDTA) which chelates papain-inhibiting calcium ions.

When all the collagenous material in the samples has dissolved the solutions were allowed to cool, then centrifuged at 2000 g at 4°C for 30 minutes. 1 μl samples of the clear, brown viscous supernatant liquid were applied to cellulose acetate paper in approximately 1 cm lines using a micro-syringe. 1 μl samples of standard GAG (1 mg/ml solution of dermatan sulphate) were also applied to the papers.

The cellulose papers were then stained in a solution of 0.2%($^{w}/_{v}$) Alcian Blue 8GX containing 0.05 M magnesium chloride, 0.025 M sodium acetate buffer (pH 5.8) in 50%($^{v}/_{v}$) ethanol:water. The papers were then destained in 5 or more changes of an aqueous solution of 0.05 M magnesium chloride, 0.025 M sodium acetate buffer (pH 5.8) until a nearly white background was obtained.

The stained bands were then cut out of the dried paper and dissolved in 1 ml of dimethyl sulphoxide (DMSO) containing 0.025 M magnesium chloride and 0.025 M sodium acetate. Absorbances were then measured at 678 nm using semi-micro

cuvettes (1 cm path length). Blanks cut from the destained papers and corresponding to the size of the stained bands were also dissolved and used as background values and were no more than 0.05 absorbance units/cm².

The amount of GAGs in the 1 μl stained strips were determined using the values obtained for the standard solution. The total GAG content in the original digest was then calculated and related to the amount of collagen present in the dry, fat free skin (see section 3.1.4.).

3.2. Histological Analysis of Dried skins.

The sampling position on the air dried skins for the histological analysis is shown in figure (3). The samples were rehydrated in 25 mM phosphate buffer (pH 7.6) at 4°C for 24 hours. They were then fixed in 5% formol-saline (Bancroft & Stevens (1982)) solution for 24 hours and stored in 70%($^{v}/_{v}$) ethanol prior to sectioning.

The fixed samples were sectioned (20 μm thick) using a freezing microtome (Reichert-Jung Cryocut E) at -25°C following the line of hair growth. The sections were stained with an aqueous haematoxylin solution (Carazzi's stain (Bancroft & Stevens (1982)), and mounted on slides using glycerol-jelly (Bancroft & Stevens (1982)).

The total thickness of the section, the thickness of the grain layer and the depth of the hair follicle were measured using a light microscope at x10 magnification. The various measurements made on the sections are illustrated in figure 5. At least three measurements were made per section and nine sections per sample were examined and mean values calculated.

Structural assessments of the collagen fibres in the top third of the corium layer in terms of compactness, orderliness and angle of weave (BLMRA (1957)) were also made on each of the sections. The sections were graded for each attribute according to the scheme given in figure 6.

Figure 5 General structure of skin (in cross-section) indicating the measurements taken in the histological assessment of Phase I and II skins.

Figure 6 Histological assessments of the corium collagen fibre structure. (Modified from BLMRA (1957)).

3.3. Hydrothermal Isometric Tension (IMT) of Dried Skins.

The sampling position on the skins for the IMT analysis is shown in figure 3. The principle of the analysis involves a strip of rehydrated skin being clamped at a fixed length, submerged in a buffer solution the temperature of which is raised and held above the shrinkage temperature of the sample. Tension (tensile force) develops in the clamped sample and this is monitored over a set period of time (Cater (1972); Haines & Shirley (1979); (1988); Trinick & Shirley (1972); Alexander *et al* (1988)).

The samples of dried skin were soaked in 25 mM phosphate buffer solution (PBS)(pH 7.4) and allowed to equilibrate for 48 hours at 4°C. Specimens approximately 1.0 cm wide and 3.5 cm long were cut using a template prior to IMT determination.

The apparatus used to measure IMT is shown schematically in figure 7. Skin samples were clamped between two stainless steel jaws and immersed in PBS. The samples were subjected to minimal tensile force and allowed to equilibrate at 25°C for about 10 minutes and "retensioned" if required. The temperature of the PBS was progressively increased from 25°C to 70°C at a rate of about 2°C/minute. The temperature of the PBS and tensile force developing in the skin samples were simultaneously plotted on the chart recorder. The resulting tensile force in the samples was monitored for at least 30 minutes after the development of the initial maximum tensile force (figure 8). From the tension (force-time) curves (a) the maximum tension or force produced ($f_{(0)}$) and (b) the force at 10 and 30 minutes after $f_{(0)}$ were noted.

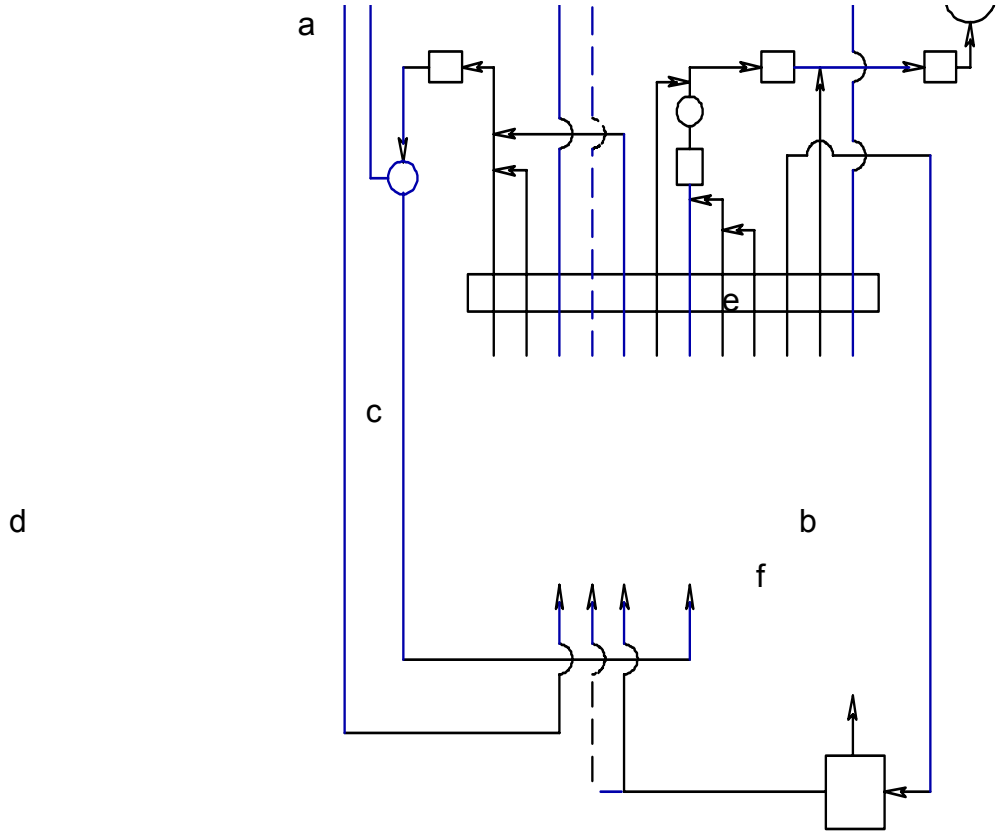
These parameters were required to calculate the relaxation of force in the samples:

$$R_{10} = \frac{f_{(0)} - f_{(10)}}{f_{(0)}} \times 100 = \text{percentage relaxation of force occurring in the 10 minutes following } f_{(0)}.$$

$R_{30} = \frac{f_{(0)} - f_{(30)}}{f_{(0)}} \times 100$ = percentage relaxation of force occurring in the 30 minutes following $f_{(0)}$.

$Z = \frac{R_{30} - R_{10}}{R_{30}}$ = fraction of the total relaxation occurring between 10 and 30 minutes.

The maximum stress (σm) produced was also calculated for each sample which is the maximum force ($f_{(0)}$) produced per cross sectional area of the sample and measured in KPa.



a - Analog-digital converter
b - Water bath, filled with buffer
c - Thermoregulator and circulation pump
d - Recorder (x-y plotter)
e - Load cell
f - Clamped skin sample

Figure 7 Schematic diagram of isometric tension apparatus

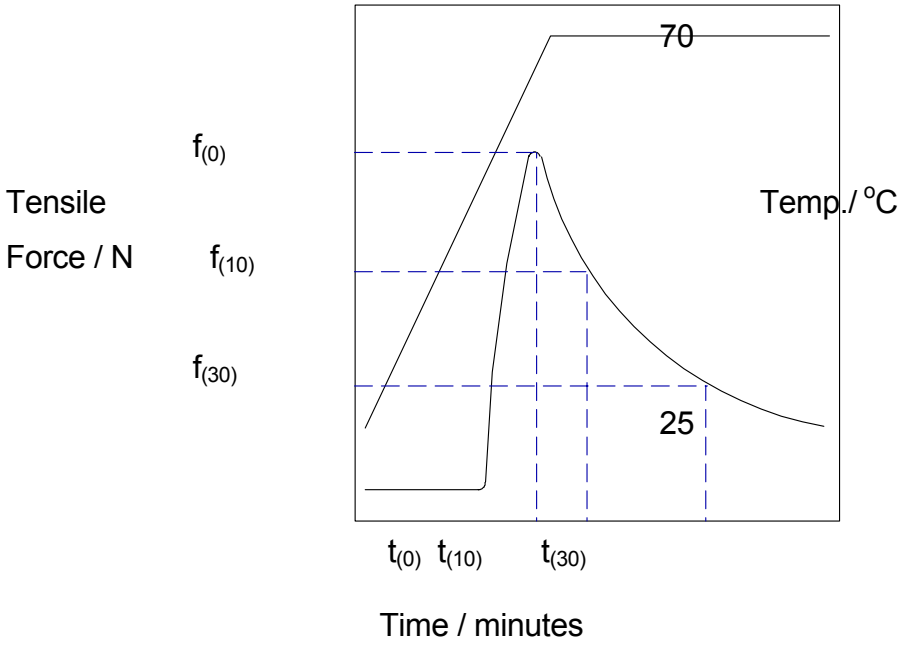


Figure 8 Example of IMT curve obtained from rehydrated skin samples. Shown is the maximum force ($f_{(0)}$) produced by a sample and forces ($f_{(10)}$) and ($f_{(30)}$) 10 and 30 minutes after $f_{(0)}$ is reached.

3.4. Chemical Analysis of Crust Leathers.

3.4.1. Chromic Oxide Content.

The chromic oxide content of a leather is defined by the quantity of chromium compounds found in it, calculated as chromic oxide (Cr_2O_3). This was determined in the leather ash, by oxidising the leather ash and iodometric titration of the hexavalent chromium ions (SLC(8) 1966).

Approximately 1 g of crust leather from the physical testing sample area (figure 3) was oxidised first by nitric acid and then by a mixture of concentrated sulphuric and perchloric acids (1:2). The mixture was heated until it turned orange. After cooling, water was added and the solution heated again until boiling. After 10 minutes the solution was allowed to cool again. This process removed any free chlorine. This solution was diluted with water to a known volume (250 ml). Aliquots (100 ml) with excess 10% potassium iodide solution were stoppered and left in the dark for 10 minutes. The liberated iodine in the solution was titrated against 0.1 M sodium thiosulphate ($Na_2S_2O_3$). The chromic oxide (Cr_2O_3) content of the leather was calculated as a percentage of the original leather weight:

$$Cr_2O_3 / g = \frac{\text{titre /ml x moles of } Na_2S_2O_3 \text{ x } 152 \text{ x } 2.5}{6 \text{ x } 1000}$$

Relative Molar Mass of Cr_2O_3 = 152

1 mole of Cr_2O_3 is equivalent to 6 moles of $Na_2S_2O_3$

$$Cr_2O_7^{2-} + 6I^- + 14H^+ \rightarrow 2Cr^{3+} + 7H_2O + 3I_2$$

$$2S_2O_3^{2-} + I_2 \rightarrow 2I^- + S_4O_6^{2-}$$

$$Cr_2O_3 / \% = \frac{\text{weight of } Cr_2O_3 / g \text{ x } 100}{\text{weight of sample / g}}$$

3.5. Physical Testing Of Leathers.

The sampling position on the crust leathers and the dimensions of the physical testing samples are shown in figures 3 and 9 respectively. All the samples were conditioned for at least 48 hours at 65 ± 2% relative humidity and 20 ± 2°C before testing. The thickness of the conditioned samples were measured using a standard type measuring gauge (BS3144:(1968) method (3)) in three locations (figure 9).

3.5.1. Tensile Strength.

The cut leather sample was clamped between the jaws of the test machine, as shown in figure 10(i), which then separate at a uniform speed until the sample breaks (BS3144:(1968) method (5)). The load that caused the test sample to break, the breaking load, and the length of the sample at break were measured. From these parameters the tensile strength and percentage elongation of the samples were calculated:

$$\text{tensile strength / Pa} = \frac{\text{breaking load / N}}{\text{cross-sectional area / m}^2}$$

$$\text{elongation / \%} = \frac{\text{length at break - initial length x 100}}{\text{initial length}}$$

An Instron 1122 testing machine was used to carry out the procedure, using a cross head speed of 100 mm per minute. Duplicate test samples were cut from the sampling area in both parallel and perpendicular directions to the back bone of the animal.

3.5.2. Grain Crack, Burst and Distension.

The tension of the test leather samples when a load was applied across the sample by a steel ball, from the flesh side as shown in figure 10(ii), was measured (BS3144:(1968) method (6)). A lastometer was used to perform the test procedure, in which clamps hold the rim of the circular, flat disc of test leather, leaving the central portion free to

move. The force was applied via the steel ball (6.25 mm diameter) which was advanced manually at a steady rate of approximately 1/5 mm per second. The amount of distension (mm) and the applied load (N) was noted when:

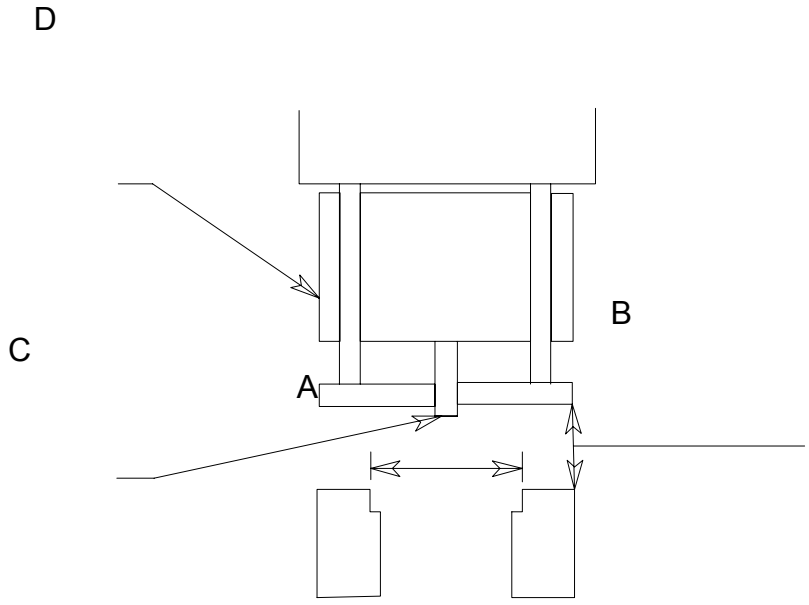
(a) the grain surface first cracked,
(b) the steel ball burst through the sample.

Figure 9 Dimensions of physical testing samples

Figure 10 Diagram illustrating the "set-up" and direction of applied forces during physical testing of trial leathers.

3.6. Softness.

The softness of crust leathers was measured using a BLC softness gauge (Stosic (1992); Alexander & Stosic (1993)). The machine works on a principle similar to that used by a lastometer. The leather was clamped between two circular plates (20 mm aperture) and a light load (500 g) was applied to the top, grain surface (figure 11). The distension caused by the loading was measured. The softer the leather the further the leather stretched giving a higher softness value. The softness gauge has been shown to correlate with hand gradings of leathers (Alexander & Stosic (1993)).



A - Aperture in which leather is stretched

B - Clamps to hold leather

C - Rod which applies load to leather

D - Weight (500 g) which applies load to leather

Figure 11 Cross-sectional view of the working head of BLC softness gauge.

Chapter 4 Results and Discussion

4.1. Animal Data.

4.1.1. Phase I.

Data were forwarded from Brazil on the carcass weights of the animals, the trimmed, green and subsequent dried skins. Figure 12 illustrates the relationship between the green and dried skin weights and slaughter weight of the animal (the carcass plus green skin weight). The weight of the skin, both in the green and dried state, increases with the weight of the carcass and by inference the weight of the live animal.

Figure 13(i) shows the dependence of the slaughter weight of animals on their ages. All animals increase their weight with age. Female animals have their largest increase in weight between age groups 0 and 2 after which their weights remain relatively stable. Both male and castrate animals continue to increase their body weights with age. The same pattern is also seen in the weights of green and dried skins (figures 13(ii) & (iv)).

However if the skin weights are compared directly with the slaughter weights of the animals (figures 13(iii) & (v)), a clearer more direct relationship between the two factors emerges for each of the sex groups; i.e. skin weight increases with body weight. This trend is in line with the fundamental function of the skin to cover the "biomass" of an animal. Therefore quite naturally the bigger the biomass of the animal the heavier or greater the mass of its skin.

Hides and skins in the leather trade are brought and sold on the basis of weight. Therefore it is important to suppliers of raw material and the leather industry to be able to estimate the quantity of skin that can be obtained from an animal. Adegboye *et al* (1984) related the green skin weight to the live weight of Nigerian goats in terms of the "Dermal-Somatic Ratio" or DSR. The latter, in practice, is the weight of the green skin as a percentage of the animal's live weight. Unfortunately DSRs for the trial goats could not be calculated as the live weight or the dressing percentage[3] of the Brazilian goats was not provided. However ratios for green and

[3] Dressing percentage is the ratio of carcass weight to live animal weight.

dried skins were calculated based on slaughter weight (carcass weight and green skin weight) and are shown in tables (11)&(12). The male animals had predominantly the highest ratios in each age group, with the ratios for both green and dried skins increasing with age. The ratios for both female and castrate animals remained relatively stable with age.

Table 11 Dermal-Stomatic Ratios (%) for Phase I green goat skins. (Mean values).

SEX	AGE GROUP			
	0	2	4	6
MALE	11.7	12.0	13.4	13.1
CASTRATE	11.5	11.0	11.5	11.3
FEMALE	10.4	11.7	10.7	10.9

Table 12 Dermal-Stomatic Ratios (%) for Phase I dried goat skins. (Mean values).

SEX	AGE GROUP			
	0	2	4	6
MALE	4.1	4.3	5.0	6.9
CASTRATE	4.7	3.4	4.3	4.6
FEMALE	4.9	4.0	4.6	4.1

The DSR values for green and dried skins calculated from Phase I data were larger than those quoted by other workers (table (13)). It is important to note that DSR is usually quoted on the basis of live weight, however this may be "as is", fasted or empty body weight. Owen *et al* (1977) have shown that the contents of a goats alimentary

tract can form as much as 29 % of its live weight which makes meaningful comparisons difficult. The slaughter weights of Phase I goats, as already mentioned, were estimates made from carcass and green skin weights. From simple linear regression analysis of Phase I slaughter and skin weights (table (14)) it can be seen that although the relationship between the slaughter weight and green skin weight varies with sex, the overall relationship closely resembles that quoted for Brazilian goats by Bellaver (1980). This type of information allows a quick and reliable method for estimating the weight of fresh and dried goat skins from the live animal as well as the expected weight yield after air drying (table (15)).

Table 13 Dermal-Stomatic Ratios of various goats, calculated for fresh (green) and dried skins.

DSR / %	SKIN	COUNTRY (BREED/SEX)	REFERENCE
6.6	fresh	Nigeria	Adegboye (1984)
7.5	fresh	Australia	McGregor (1992)
7.2*	fresh	USA (small males)	Lapido (1973)++
7.6*	fresh	USA (large males)	Lapido (1973)++
8.6	fresh	Australia	Greenwood *et al* (1992)
9.0	fresh	Malaysia	Devendra (1966)+
9.1	fresh	Tunisia (small)	Schröer (1986)
4.7	fresh	Tunisia (large)	Schröer (1986)
4.9*	fresh	Brazil (small 8 kg lw)	Bellaver (1980)
8.7*	fresh	Brazil (large 32 kg lw)	Bellaver (1980)
2.7*	dried	Brazil (small 8 kg lw)	Bellaver (1980)
2.6*	dried	Brazil (large 32 kg lw)	Bellaver (1980)

+ quoted in Adegboye (1984)

++ quoted in McDowell and Bove (1977)

* calculated from reference data

---

lw live weight

Table 14 Relationship between slaughter weight (x) and green and dried skin weight (y) for Phase I goats obtained from simple linear regression analysis of data.

SLAUGHTER WEIGHT / kg	GREEN SKIN WEIGHT / kg		DRY SKIN WEIGHT / kg	
	Equation	r	Equation	r
MALE	0.14x - 0.13	0.92	0.05x - 0.07	0.78
CASTRATE	0.09x + 0.25	0.92	0.04x + 0.02	0.85
FEMALE	0.11x + 0.07	0.92	0.04x - 0.01	0.80
ALL	0.10x + 0.17	0.91	0.04x + 0.01	0.82
BELLAVER (1980)*	0.10x - 0.41	0.89	0.03x + 0.01	calculated

r - correlation coefficient

* - based on live weight

Table 15 Relationship between green skin weight (x) and dried skin weight (y) for Phase I goats obtained from simple linear regression analysis of data.

DRIED SKIN WEIGHT / kg	GREEN SKIN WEIGHT / kg	
	Equation	r
MALE	0.39x - 0.13	0.78
CASTRATE	0.42x + 0.62	0.88
FEMALE	0.36x + 0.45	0.75
ALL	0.39x - 0.18	0.83
BELLAVER (1980)	0.23x + 0.13	0.93

r - correlation coefficient

4.1.2. Phase II

This phase of the project assessed the effect of one biological factor, nutritional stress, on skin. The animals had been castrated and had the same approximate age. However their slaughter weights were not the same. This difference was a consequence of the nutritional regimes the animals had been kept under (figure 14(i)). The original nutritional experiments had aimed at producing control animals with 18 and 20 kg body weight for the low and high nutritional groups respectively (Figueiredo (1990)). The mean slaughter weights achieved were slightly higher at 19.7 and 22.3 kg. These body weights are not significantly different and it is only with the additional nutritional stress of the worm burdens that the differences between the two nutritional levels increased. With increased nutritional stress the slaughter weight decreased. The difference between the mean slaughter weights of the two nutritional levels was significant ($p<0.05$) only at the two extremes in the trial; i.e. control HN and LNHW.

Only the weights of the air dried goat skins were provided by EMBRAPA for this phase of the project. Lighter skins were obtained from the more nutritionally stressed animals. Although this trend is evident, (figure 14(ii)), the groups are not significantly different. This finding is in contrast to that shown in figure 14(iii) where skin weights for each of the slaughter weight groups are shown. It is evident that the slaughter weight has a more profound effect on the skin weight than the nutritional treatment regime. Therefore analyses of the properties of the skins and leather not only took into account the nutritional treatments but also the slaughter weights of the animals.

It should be noted that the slaughter weight referred to in Phase II is the actual weight of the animal after slaughter rather than the carcass plus green skin weight. Unfortunately the carcass weights were not available which makes it difficult to relate directly the animal data of Phases I and II. The DSRs were calculated for Phase II dried skins (table (16)), which were lower than the ratios obtained for Phase I's castrate age group 0, but approached the levels for dried skins quoted by Bellaver (1980) in table (13). The slaughter and dried skin weights of Phase II's goats were greater then those of the corresponding Phase I group. As the total body weight of an animal increases the

percentage the skin accounts for decreases giving lower DSR values (Schröer (1986)).

Table 16 Dermal-Stomatic Ratios of Phase II dried goat skins.

NUTRITIONAL TREATMENT	WORM BURDEN		
	CONTROL	LOW	HIGH
LOW	3.1	3.4	3.2
HIGH	2.9	3.1	3.2

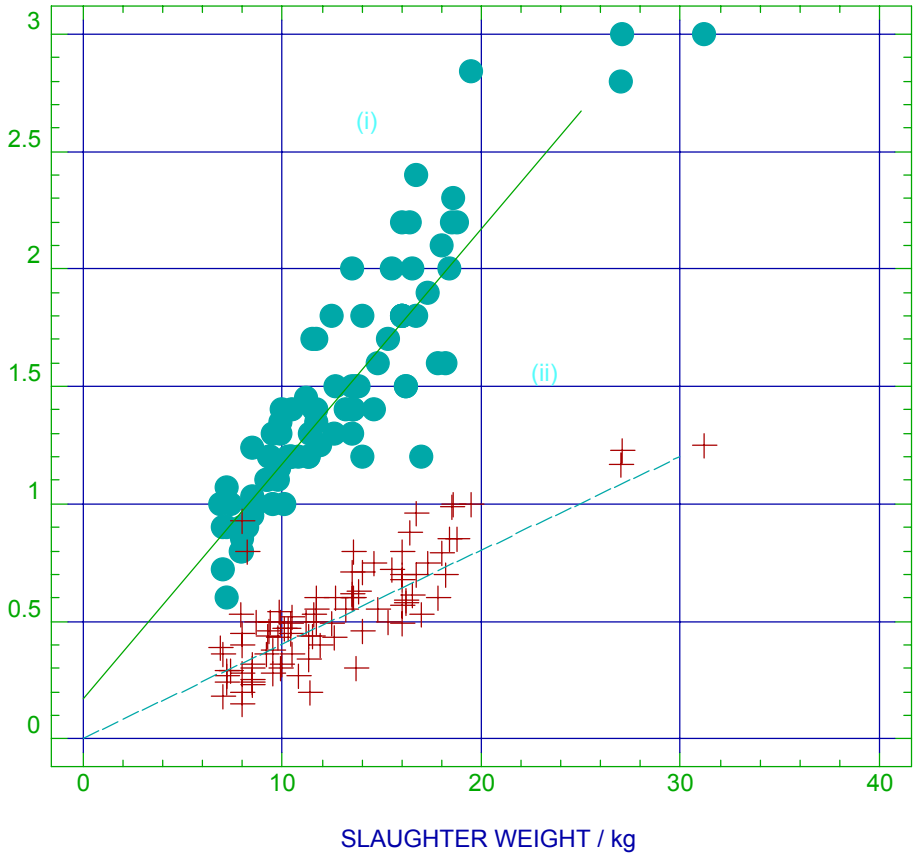


Figure 12 Slaughter weight of Phase I goats as a function of (i) green skin and (ii) dried skin weights.

Regression lines:

(i) green skin weight = 0.10 slaughter weight + 0.172 (r=0.91)
(ii) dried skin weight = 0.04 slaughter weight + 0.003 (r=0.82)

Figure 13 Phase I animal data.
(Mean values, standard deviation error bars)

(i) Slaughter weights of animals in the 4 age groups.
(ii) Green skin weights from animals in the 4 age groups.

(iii) Green skin weights from animals in the 4 weight groups.
(iv) Dried skin weights from animals in the 4 age groups.
(v) Dried skin weights from animals in the 4 weight groups.

Figure 14 Phase II animal data.
(Mean values, standard deviation error bars)

(i) Slaughter weights of animals in the 6 nutritional treatment groups.
(ii) Dried skin weights from animals in the 6 treatment groups.
(iii) Dried skin weights from animals in the 3 slaughter weight groups.

4.2. Goat Skin Analysis.

4.2.1. Chemical Analysis.

4.2.1.1. Moisture Content.

4.2.1.1.1. Phase I Skins.

The amount of moisture found in air dried male skins was marginally higher, at around 15%, than that found in the female or castrate skins. Comparisons between the three sexes on the basis of both weight and age parameters showed the same trend, with the male skins having the highest moisture content and those from castrated animals the lowest (figures 15(i) & (ii)). Intra-sex comparisons of moisture contents with age and weight showed no statistical differences in the skins, the levels remaining relatively stable.

4.2.1.1.2. Phase II Skins.

The moisture contents of Phase II air dried skins from LN animals showed little variation, with a only a slight increasing trend in moisture contents with increasing nutritional stress in the HN treatment groups (figure 16(i)). This pattern mirrors the trend of decreased moisture contents seen with increased slaughter weight (figure 16(ii)). However these differences were not significant.

4.2.1.2. Fat Content.

4.2.1.2.1. Phase I Skins.

Figure 15(iii) shows the dependence of the fat content of the skins (on a moisture free basis) on the age of the animal. No significant differences were found between the sexes up to age group 6 where the highest levels of fat were found (4.7%). Only castrated animals showed an increase in skin fat content with increased age. No significant differences were found in the levels of fat in the skins over the first three weight groupings (figure 15(iv)). Both female and castrate skins tended to have increased amounts of fat as the body weight of the animals increased.

4.2.1.1.2. Phase II Skins.

Figure 16(iii) shows how the fat content (on moisture free basis) of the skins varied with the nutritional treatments. The fat contents of each of the LN treatments were lower than the corresponding HN group. The greatest difference was seen between the two control groups with the least difference between the two HW groups; i.e. the most stressed groups. However again these differences were not significant. Increased slaughter weight of the animal was seen to produce increasing fat contents in the skins (figure 16(iv)). The differences between the highest and lowest weight groups was significant only at the 90% level ($p<0.10$).

4.2.1.3. Nitrogen Content.

4.2.1.3.1. Phase I Skins.

The nitrogen contents (on a moisture and fat free basis), which give an indication of the levels of proteins present in the skin, were significantly higher in male skins than castrate skins on both an age and weight basis (figures 15(v) & (iv)). No significant differences were detected within the three sex groups with increasing age or weight at slaughter.

4.2.1.3.2. Phase II Skins.

Total nitrogen contents of Phase II skins showed the greatest variation between the two highest stressed treatment groups; i.e. LNHW and HNHW (figure 16(v)). The LNHW group had the highest nitrogen content (15.1%). Again, however, none of these differences were significant for either the nutritional factors or the slaughter weights of the animals (figure 16(vi)).

4.2.1.4. Chemical Analysis Discussion.

The results from Phase I chemical analysis of skins mirror findings on goat carcass composition (Wilson (1958); Kirton (1970); Louca *et al* (1977)) where male animals have less fat, more protein and higher water contents than female animals. It is uncertain if the higher levels of moisture present in male dried skins were a consequence of either higher absolute levels of moisture in the green skin (table (17))

or an inverse relationship with the fat content of the skin. Both male and castrate skins gave a significant negative correlation coefficient between % fat and % moisture levels.

Intact male animals grow faster with more efficient feed conversion up to about 9 months (Louca *et al* (1977); Spiker *et al* (1992)) when growth appears to cease, while the castrated animal continues growing, producing fatter carcasses. Although in this study we were unable to identify the exact age of the animal the increase in protein (% nitrogen) in castrate skins with both increasing age and weight could be indicative of this continued growth. Significant positive correlations were found between both the % fat and % nitrogen levels and animal age, slaughter weights and green skin weights in the case of castrated goats. Significant negative correlations were discovered between the % nitrogen levels and animal age, slaughter weights and skin weight in the male skins reflecting lower levels of protein synthesis with increasing age and maturity.

Female animals have a relatively slower growth rate than the males or castrates, tending to a lower weight at an equal age and a lower mature weight. In male and female skins the correlation between the nitrogen content and the animal age was slightly greater than the correlations with the slaughter or skin weight, suggesting a more age influenced interaction.

The same inverse correlation between the moisture and fat contents of Phase I skins was also found in Phase II. The reduction in the fat content with physiological stress was most pronounced in the HN skins, where the fat content in the skins was reduced to a level approaching that of the LN groups. Russell *et al* (1977) and Bruyn *et al* (1987) showed that skin, relative to other body tissues, is an early maturing organ with the skin components also maturing early with the possible exception of the fat deposits. These deposits function as a potential reservoir for growth of the other body tissues (Bruyn *et al* (1987)).

Nutritional restriction of an animal has an effect on the fat content of skin especially during early maturation where the fat deposits may be mobilised to compensate for

inadequate carcass fat levels. This pattern was seen to a certain extent in the nutritional phase studies where the higher nutrition groups showed the greatest range of fat contents which were reduced with increasing nutritional stress. The low nutrition animals could be considered to be at their "base" fat level with no reserves to mobilise so that increased stress did not alter the fat levels. The degree of nutritional stress in the trial may not have been sufficient to reduce the fat contents below this 5% point. In effect the animals could be considered to have been on a maintenance rather than below maintenance level of nutrition.

Tudor (1992) related diet to the amount of fat deposited on cattle carcasses. Grain fed cattle deposited significantly more fat than cattle finished on pasture with associated reductions in carcass water, protein and ash contents, an effect reflected in the results from the trial goat skins. However it is uncertain whether the high fat levels were a result of either faster growth or the diet.

The levels of fat found in Phase II skins, whether on low or high nutrition, were considerably higher than those seen in the corresponding Phase I skins. The castrated age group 2 animals had 2.2% fat compared to around 5% in the LN groups of Phase II. This pattern is an indication that the general population of goats sampled in Phase I were probably on a lower plane of nutrition than the designated "low nutrition" group of Phase II. The two groups of animals had also been slaughtered in different seasons; i.e. Phase I in the summer and Phase II in the autumn. This slaughter timing may also have influenced the nature of the skins. In both sets of skins the fat contents were highly variable.

Table 17 Moisture contents of Phase I skins (Mean values).

MOISTURE CONTENT / %	SEX OF ANIMAL		
	MALE	CASTRATE	FEMALE

REMOVED ON AIR DRYING	64.0	62.5	61.0
REMAINING IN AIR DRIED SKINS	15.3	14.2	13.8
CALCULATED MOISTURE IN GREEN SKINS	71.4	69.4	69.0

Figure 15 Phase I chemical analysis data of dried goat skins.
(Mean values, standard deviation error bars)

(i) Moisture contents of skins from animals in the 4 age groups.
(ii) Moisture contents of skins from animals in the 4 weight groups.
(iii) Fat contents of skins from animals in the 4 age groups.
(iv) Fat contents of skins from animals in the 4 weight groups.

(v) Nitrogen contents of skins from animals in the 4 age groups.
(vi) Nitrogen contents of skins from animals in the 4 weight groups.

Figure 16 Phase II chemical analysis data of dried goat skins.
(Mean values, standard deviation error bars)

(i) Moisture contents of skins from animals in the 6 nutritional groups.
(ii) Moisture contents of skins from animals in the 3 weight groups.
(iii) Fat contents of skins from animals in the 6 nutritional groups.
(iv) Fat contents of skins from animals in the 3 weight groups.

(v) Nitrogen contents of skins from animals in the 6 nutritional groups.
(vi) Nitrogen contents of skins from animals in the 3 weight groups.

4.2.2. Biochemical Analysis.

4.2.2.1. Collagen Content.

4.2.2.1.1 Phase I Skins.

Although in figures 17(i) & (ii) a slight trend of decreasing skin collagen content with both age and weight were apparent these differences were not significant. However in age group 6 male skins did contain significantly less collagen than the skins from castrated and female animals.

4.2.2.1.2. Phase II Skins.

The collagen content (as % of dry skin weight) of the skins (figure 18(i)) mirrors the trends found for the nitrogen contents in section 4.2.1.3. The less stressed HN animals, i.e. HN and HNLW, tended to have higher collagen levels than the LN animals, with levels converging under high stress conditions i.e. HW. Slaughter weights of the animals did not appear to have any effect on the collagen contents of the skins (figure 18(ii)).

4.2.2.2. Glycosaminoglycan (GAG) Content.

4.2.2.2.1. Phase I Skins.

The GAG content (in terms of the proteoglycans dermatan sulphate (DS) and hyaluronic acid (HA)) did not vary significantly with the age or weight of the animal except in the case of the young male animals (figure 17(iii)). There was a significant increase in GAG content from group 0 to 2 and then a fall to the oldest animals. The levels of GAG in castrate skins were significantly higher than in female and male skins in the two extreme age groups 0 and 6. The weight of the animal at slaughter appeared to have less effect on the levels of GAG in the skins, although castrate animals still had the highest GAG content in each weight group (figure 17(iv)).

4.2.2.2.2 Phase II Skins.

The GAG content of the Phase II skins was greater in the LN treatment groups than in the HN groups (figure 18(iii)). This relationship was emphasised by a significant

negative correlation between the levels of GAG and the slaughter weight of the animal (figure 18(iv)).

4.2.2.3. Biochemical Analysis Discussion.

The slight variation in collagen content exhibited in Phase I can be considered again as a reflection of the early maturing nature of the skin. Wang (1992) found that the collagen content of dried Brazilian goat skins increased significantly up to about 8 months of age. Most of the expected increase in skin collagen would have occurred within the 0 age or 1 weight groups and as such would not be highlighted by this study.

Hyaluronic acid and dermatan sulphate are comparatively minor components of the skin by weight, but occupy a large volume in the interfibrillary spaces of the collagen matrix. The amounts of these soluble non-collagen proteins tend to decrease with the physiological age of the skin as the collagen matures, fibril diameters increase and the spaces in the extra cellular matrix decrease (Haines (1985)). In Phase I the amounts of GAG present initially increased with both increasing age and slaughter weight in the case of male and female animals. This trend may be a reflection of the physiological rather than the temporal age of the skin. However, the variation in GAG content may be caused by an alteration in the relative amounts of HA and DS. Loewi & Meyer (1958), have shown that there is a decrease in HA with increasing age (in pig skin), along with an increase in the levels of sulphonated GAGs.

Correlation analysis of the biochemical data showed a significant positive correlation between the amounts of GAG in the skin and the percentage depth of the hair follicle in the histological analysis of the skin, suggesting that GAGs may be associated with either the hair follicle sheath or the supporting fibrous framework surrounding the hair follicle. Reed (1953) states that the regions in a skin which are particularly rich in mucoid (DS and HA) are the papillary layer of the corium (grain layer), especially around the hair follicles, the junction of this layer with the epidermis and the vascular processes in the corium.

A lesser but still significant negative correlation of GAG with the percentage moisture in the dried skins was also identified. Both HA and DS are associated with a considerable degree of hydration and play an important role in the extra cellular matrix with their

ability to bind large amounts of water in the intracellular spaces (Hay (1981); Bowes *et al* (1951)).

Severe nutritional restriction can affect the nature and level of components in skin. Rao *et al* (1985) found that there was a decrease in the catabolism of collagen and an increase in the catabolism of glycoproteins and GAGs in the skins of rats kept on protein deficient diets. Diet has been shown in Phase II to influence the collagen and GAG contents of goat skins. The skins from animals on low nutritional diets tended to have less collagen and higher levels of GAGs than those from high nutrition groups. However the dietary conditions in these trials were less restrictive than those quoted by Rao *et al* (1985) and the catabolism or turnover rate of skin components were not determined.

Figure 17 Phase I biochemical analysis.
(Mean values, standard deviation error bars)

(i) Collagen content of the 4 age groups.
(ii) Collagen content of the 4 weight groups.

(iii) GAG content of the 4 age groups.
(iv) GAG content of the 4 weight groups.

Figure 18 Phase II biochemical analysis.
(Mean values, standard deviation error bars)

(i) Collagen content of the 6 nutritional treatment groups.
(ii) Collagen content of the 3 slaughter weight groups.

(iii) GAG content of the 6 nutritional treatment groups.
(iv) GAG content of the 3 slaughter weight groups.

4.2.3. Histological Analysis.

4.2.3.1. Skin Thickness.

4.2.3.1.1. Phase I Skins.

Castrated goats produced the thickest skins (1.15 mm) in the youngest age group 0 (figure 19(i)), equivalent male and female animals producing skins 0.75-0.85 mm thick. Only the thickness of male skins increased significantly with age, skins from animals in the oldest age group 6 approaching the proportions of those obtained from the castrated animals i.e. over 1.2 mm. The thickness of female skins did not alter with age remaining at about 0.85 mm. When the skins were considered on a slaughter weight basis, the same trends in skin thickness were recorded, but were more clearly defined (figure 19(ii)). Again male and female skins started at similar thicknesses (about 0.75 mm), male skins increased sharply in thickness over weight groups 2 and 3 to reach the proportions of skins from castrated goats (1.6 mm). There were no significant increases in the thickness of female skins.

4.2.3.1.2. Phase II Skins.

Overall the HN animals produced thicker skins than those on LN regimes (figure 19(iii)). However, the differences between the two groups and treatments were not significant. Figure 19(iv) shows a marked trend for increased skin thickness with increased slaughter weight.

4.2.3.2. Grain and Corium Ratios.

4.2.3.2.1. Phase I Skins.

Although the total thickness of the skins and the absolute grain thickness did vary, the percentage of the total skin thickness taken up by the grain varied very little between the three sexes when compared on an age basis (table (18)). The weight of an animal had a stronger influence on the grain proportion of the skins than age (table (19)). Grain thicknesses were very similar in male and female skins and increased with weight, yet in male skins the grain percentage decreased with weight. The grain layer of the skin from castrated animals was significantly thicker than both male and female skins' while the grain percentage of the total thickness followed the same downward

trend as male skins. The proportions of the different skins layers is diagrammatically represented in figure 20.

Table 18 Grain layer thicknesses and hair depths plus percentages of Phase I goat skins based on the age of animals at slaughter (mean values).

SEX AGE GROUP	MALE 0 2 4 6	CASTRATE 0 2 4 6	FEMALE 0 2 4 6
Grain layer thickness / μm	177 219 193 263	278 266 212 327	200 218 236 207
Hair depth / μm	320 474 502 447	573 587 464 656	354 392 411 373
Grain ratio of total skin thickness / %	24 21 18 21	25 22 25 23	24 24 29 25
Hair depth ratio of total skin thickness / %	43 47 45 35	51 49 55 46	42 44 51 45

Table 19 Grain layer thicknesses and hair depths plus percentages of Phase I goat skins based on the weight of animals at slaughter (mean values).

SEX WEIGHT GROUP	MALE 1 2 3 4	CASTRATE 1 2 3 4	FEMALE 1 2 3 4
Grain layer thickness / μm	178 218 223 -	289 250 291 341	180 217 232 -
Hair depth / μm	327 486 481 -	592 544 610 714	316 384 418 -
Grain ratio of total skin thickness / %	24 21 18 -	25 22 23 21	24 25 27 -
Hair depth ratio to total skin thickness / %	43 47 39 -	51 48 48 41	42 44 48 -

4.2.3.2.2. Phase II Skins.

The LN regimes produced skins with a higher percentage grain content (to total skin thickness) compared to the HN treatments. Increasing the stress in terms of high and low worm burdens did not affect the ratios nor did it affect the overall skin thickness. Again the weight of the animal at slaughter appeared to have the more dominant effect

on the proportions of grain layer in the skins. Decreasing grain levels were found with increasing slaughter weight of the animal.

4.2.3.3. Hair Follicle Depths.

4.2.3.3.1. Phase I Skins.

In male and castrate skins the overall trend was for the percentage hair depth (to total skin thickness) to decrease with increasing age. Only in age groups 0 and 6 were there clear significant differences between the sexes. In skins from castrates the hair follicle depth was proportionally greater than in skins from both female and male goats at group 0 and only males at group 6.

Comparisons on weight grounds show the same pattern described for age over the first three weight groups, the absolute values increasing with increasing weight (castrate>male>female). The percentage hair depth decreased in male and castrate skins but increased in female skins with increased weight.

4.2.3.3.2. Phase II Skins.

Although no significant differences were found between the groups a trend of increasing follicle depth and slaughter weight was noted.

4.2.3.4. Assessments of Collagen Fibre Structure.

4.2.3.4.1. Phase I Skins.

No significant differences were found in the compactness of the corium fibres, either within or between the different age groups. However there was a slight trend for the structure in male and castrate animals to become more compact with age and weight, while the structure of female skins tended to become more loosely woven (figures 21(i) & (ii)). Similar trends were seen when compared on a slaughter weight basis. The difference between the male weight groups 1 and 3 was significant ($p<0.10$).

The trend with age for the orderliness assessment of the fibres was a shift towards a more disordered structure in female and castrate skins, while male skins tended to become more ordered (figure 21(iii)). However only the increase in female values from age groups 2 to 6 were statistically significant ($p<0.10$). Both castrate and female skins had lower values (i.e. more ordered structure) than male skins except in the oldest age

grouping. The same trends were seen in the weight comparisons of fibre structure but no significant differences were noted (figures 21(ii), (iv) & (vi)).

The angle of weave of the corium collagen fibres increased significantly with the age of the animal for all three sexes (figure 21(v)). The majority of this increase seemed to occur between the first two age groups in the case of female and castrate animals ($p<0.01$ for the increase between groups 0 and 2), while being more evenly spread between the age groups of male skins ($p<0.01$ for the increase between age groups 0 and 4). Again the same trends were seen if the assessments were considered on a slaughter weight basis (figure 21(vi)). Only the overall male and female increases were statistically significant ($p<0.01$ between weight groups 1 and 3).

4.2.3.4.2. Phase II Skins.

Mean values of the histological structural assessments are shown in figures 22(i)-(vi). No significant differences were found in the assessment of the compactness, orderliness or angle of weave of the collagen fibres in the corium of the skins from both nutritional and slaughter weight groupings.

4.2.3.5. Histological Analysis Discussion.

The thickness of the skin in the case of males and castrates gave significant positive correlation coefficients with the animal's weight (and at a lower level with age). Female skins showed the same correlation but at a lower significance. This pattern suggests that females may have obtained a mature state (i.e. in terms of thickness) at an earlier age (or weight) than males and castrates. The latter two groups tend to reach a greater body weight (as a result of higher rates of growth) at an earlier age compared with the females, giving the animals thicker skins when compared at the same age.

The relationship between skin thickness and body weight may also explain the differences seen between male and castrated animals. If castrates had a higher rate of growth over a period within age group 0 or weight group 1, which then decreased, for example over weight groups 1 and 2, then this would account for the "catching up" of

male skins during the older and heavier groupings. Male skins show a relatively steady increase in thickness with age and slaughter weight of the animal. The same rationale can also be applied to differences in body weight and skin thickness caused by nutritional restriction. Bruyn *et al* (1987) has also shown that severely nutritionally stressed animals produce thinner skins.

The percentage grain and percentage hair follicle depths give a very high positive correlation for female and castrate skins, while in male skins it is not significant. This pattern coupled with the fact that the skin thickness and percentage grain give significant negative correlation coefficients for all three sexes, indicate that the percentage depth of the hair follicle is a sexually influenced characteristic of the skin. Although male and castrate skins increase in thickness (both in the grain and corium layers) with age and weight, it is the increase in the corium that accounts for the greater proportion of this increase. Compared to the corium the grain layer remains relatively constant with increased age and weight.

The whole thickness of the dermis and its architecture is known to alter in response to the hair growth cycle, becoming thicker when the hairs are actively growing (anagen phase) and thinning during the resting period (telagen phase). The supporting framework and pilosebaceous structures also grow with the growing hair follicle and regress in the resting phase (Jarrett (1974)). In long haired breeds of animals the grain layer forms a greater percentage of their total thickness compared to short haired breeds irrespective of the thickness. Hair follicle depths of hides has been used to sub-classify hide types and animals (Gbolagunte *et al* (1984)). Cattle that were tolerant to hot environments were found to have shallow hair follicle depths, less than 1.5 mm (Jenkinson & Nay (1973)).

When comparing a grain layer with a layer of equal thickness from the corium, the grain layer will tend to be stronger. However, as the corium becomes thicker and the fibre bundles become interwoven, so the strength of the leather (or skin) comes mainly from the corium, and so in this way the ratios of grain to corium in a leather can be an

important factor, influencing the physical properties of the skin. This trend can be especially important where the thickness of the leather is reduced for a particular end use increasing the grain to corium ratios.

The main structural changes in the skin, with age and weight, take place in the corium. This is especially the case in male and castrate animals where the major part of the increase in skin thickness was in the corium. These changes in the structure of the fibrous corium have a relevance to the variations in the physical properties of the leather.

In male skin there is a tendency to shift to a more ordered, compact structure with a higher angle of weave with increasing age and slaughter weight of the animal. Significant positive correlations are found between both the compactness and angle of weave and the age, slaughter and green skin weights of male animals. Female and castrate skins show a shift towards a more disordered, loosely packed structure with increasing age and weight, but still with an increase in angle of weave.

The degree of splitting of the collagen fibres in the corium (both between fibres and within fibre bundles), produces a more open structure in the skins with a greater flexibility in the fibre bundles. The degree and frequency of interweaving and overlap in the weave pattern of the corium also affects the strength of the skin. Positive correlations between the angle of weave and compactness for tensile strength and % elongation in male skins support this conclusion, along with negative correlations between tensile strength and compactness in castrate skins.

Differences in the corium fibre structure in male animals appear to be related to the skin thickness, in particular the compactness and angle of weave values. Significant positive correlations were obtained between both these factors and the thickness of the skin and corium layers, but similar correlations are not found in female or castrate skins. The lower the angle of weave of the corium fibres (and the less interweaving present), the less the ability of the material to extend and stretch when pressure is applied across

the fibres. Negative correlations are seen for each of the sexes in grain crack and grain burst distensions with angle of weave of the skins.

The standard deviations of Phase II structural assessments were considerably lower than those found in Phase I. This pattern may be due to the more controlled conditions Phase II groups were kept under. Phase I skins were from a diverse range of the general population of animals. Phase II skins also tended overall to have a less compact, more disordered and lower angle of weave than the corresponding castrate age grouping in Phase I.

Figure 19 Phase I and II skin structure.
(Mean values, standard deviation error bars)

(i) Total skin thickness of the 4 phase I age groups.
(ii) Total skin thickness of the 4 phase I weight groups.

(iii) Total skin thickness of the 6 phase II nutritional groups.
(iv) Total skin thickness of the 3 phase II weight groups.

Figure 20 Diagrammatic representation of the structural layers in Phase I goat skins (Mean values)

Figure 21 Phase I assessment of corium collagen fibre structure (Mean values, standard deviation error bars)

(i) Compactness values of the 4 age groups.
(ii) Compactness values of the 4 weight groups.
(iii) Orderliness values of the 4 age groups.
(iv) Orderliness values of the 4 weight groups.

(v) Angle of weave of the 4 age groups.
(vi) Angle of weave of the 4 weight groups.

Figure 22 Phase II assessment of corium collagen fibre structure (Mean values, standard deviation error bars)

(i) Compactness values of the 6 nutritional treatment groups.
(ii) Compactness values of the 3 slaughter weight groups.
(iii) Orderliness values of the 6 nutritional treatment groups.
(iv) Orderliness values of the 3 slaughter weight groups.

(v) Angle of weave of the 6 nutritional treatment groups.
(vi) Angle of weave of the 3 slaughter weight groups.

4.2.4. Isometric Tension (IMT) and Relaxation.

4.2.4.1. Phase I (Male skins only).

No significant effects of age or slaughter weight could be discerned from the IMT results. It was very noticeable that the variation within both the age and weight groupings was considerable, particularly in the calculated R_{10}, R_{30} and Z values. For example the R_{10} values in age group 0 ranged from 0 to 33%. The mean R_{10}, R_{30}, Z and maximum tension (σm) values for Phase I male skins are given in figures 23(i)-(viii).

4.2.4.2. Phase II Skins.

No significant effects of nutritional or weight factors were seen in the relaxation of tension values at 10 or 30 minutes (figure 24(i)-(iv)). There was very little relaxation in tension observed in any of Phase II skins even after 30 minutes. The maximum R_{30} value was 10%, for one skin only. No significant differences were seen in the derived Z values (figures 24(v) and (vi)).

The maximum tension (σm) produced by skins under isometric tension increased with increased nutritional stress and was greater for the LN than the HN treatments (figure 24(vii)). The values tended to converge under the harshest conditions i.e. HW. The σm values also decreased with increasing slaughter weight (figure 24(viii)).

4.2.4.3. IMT Discussion.

Isometric tension and relaxation studies have been widely used to monitor the natural maturation processes that occur in skin (Haines & Shirley (1988); Kopp & Bonnet (1987); Le Lous *et al* (1985)), the effects of artificial aging and different curing and tanning processes (Alexander *et al* (1988); Hanacziwskj *et al* (1989); Urbaniak (1973)).

The principle relies on the fact that if a piece of skin is held in a liquid above its shrinkage point (the point at which the collagen molecules collapse), then the rate at which the resulting tension declines is a reflection of the stability of the inter- and intra-molecular crosslinks.

Through these studies it has been shown that skins from immature animals exhibit a considerable reduction in tension within ten minutes of reaching the maximum tension i.e. they have high R_{10} values. This has been related to the high levels of thermolabile bonds in the immature skins, which decrease as the animal becomes older. From this work it has been stated that if R_{10}<10% and R_{30}<15% the skins can be termed mature. The derived Z value relates the fall in tension between 10 and 30 minutes after maximum tension to the total amount of relaxation occurring tin the 30 minute period and is stated to be dependent on the amount of slowly breaking bonds present in the skins.

From the initial analysis of Phase I male skins the expected relationship between the age of the animal and the amount of relaxation exhibited was not apparent. As already stated the amount of variation within both the age and weight groups was considerable. The variation exhibited in the age groupings could be attributed to the relative inaccuracy of the method used to age the animals i.e. by dentation. If the R_{10} values are broken down into groups relating to the "degrees of maturity" (i.e. 0-1% - mature, 2-10% - intermediate and 11-50% - immature) 80% of the skins in age group 0 exhibited immature or intermediate maturity (figure 25(i)). It can also be seen that the numbers of mature skins increases markedly with age up to age group 4. The trend is not seen when comparing weight groups (figure 25(ii)). The immature categorising of the 2 skins in the oldest age group 6 was unexpected.

The maximum tension (σm) obtained from skins has also been related to the age or maturity of the animal. This parameter depends on all the different types of bonds present in the skin both labile and non-labile, and younger skins tend to exhibit lower values than older mature animal. In this study the initial results showed no relationship between the age or weight grouping and the σm produced. However if the σm values for the age and weight groups are categorises according to the R_{10} values as before then differences can be discerned (figures 25(iii) & (iv)). The σm values within the youngest and lightest groupings show significant differences between the 3 maturity categories, with the immature skins having the lowest σm values and the mature skins

the highest. Interestingly there also appears to be a trend towards a decrease in σm with increasing age and weight particularly in the two extreme groups "immature" and "mature". The unusual age group 6 skins were seen to have relatively high σm values compared to the other "immature" skins in groups 0 and 2.

Figure 23 Phase I isometric tension and relaxation data (male skins) (Mean values, standard deviation error bars)

(i) R_{10} values of the 4 age groups.
(ii) R_{10} values the 4 weight groups.
(iii) R_{30} values of the 4 age groups.
(iv) R_{30} values the 4 weight groups.
(v) Z values of the 4 age groups.
(vi) Z values the 4 weight groups.

(vii) Maximum tension (σm) values of the 4 age groups.
(viii) Maximum tension (σm) values the 4 weight groups.

Figure 24 Phase II isometric tension and relaxation data (Mean values, standard deviation error bars)

(i) R_{10} values of the 6 nutritional groups.
(ii) R_{10} values the 3 weight groups.
(iii) R_{30} values of the 6 nutritional groups.
(iv) R_{30} values the 3 weight groups.
(v) Z values of the 6 nutritional groups.
(vi) Z values the 3 weight groups.

(vii) Maximum tension (σm) values of the 6 nutritional groups.
(viii) Maximum tension (σm) values the 3 weight groups.

Figure 25 Breakdown of R_{10} values and maximum tension (σm) values in Phase I age and weight groups.

(i) Percentage of R_{10} values in each of the 4 age groups.
(ii) Percentage of R_{10} values in each of the 4 weight groups.

(iii) Mean σm values of R_{10} groups in the 4 age groups.
(iv) Mean σm values of R_{10} groups in the 4 weight groups.

4.3. Leather Analysis.

114

4.3.1. Chemical Analysis.

4.3.1.1. Chromic Oxide Content.

4.3.1.1.1. Phase I Leathers (Males only).

The chromic oxide content of the leathers made from male skins in this phase of the project are shown in figures 26(i) & (ii). The percentage chromic oxide in the samples ranged from 3.1% to 5.0% and although this is a relatively small variation in absolute terms, the content varies significantly with both the age and slaughter weight of the animal. The younger and lighter the animal the higher the chromic oxide content tends to be, and the greater the variation within the age group.

4.3.1.1.2. Phase II Leathers.

Figure 26(iii) shows the chromic oxide content of leathers from the HN and LN treatment groups. The LN skins have significantly higher chrome levels than the HN skins. The additional stress of the LW and HW burdens also significantly increased the chrome contents of the leathers. The weight of the animal at slaughter also appears to affect the uptake of chrome by the leathers (figure 26 (iv)), although this inverse relationship was not as significant as the nutritional factors. The range of chrome contents was found to be slightly higher than those in Phase I (3.2% to 5.5%)

4.3.1.1.3. Chemical Analysis of Leather Discussion.

The amount of chromium taken up by a leather is known to have significant effects on the storage properties of wet blue. Shirayama (1979) quotes a minimum content of around 2.5% to prevent loss of tensile strength and grain damage during storage of bovine wet blue. All the leathers made from the skins in both Phases of the project contained more than 2.5% chrome and were within the normal acceptable levels for wet blue.

For Phase I male skins the chromic oxide content was found to have a negative correlation of 0.7 for both age and weight. There was also a negative correlation between chrome content of the leather and the collagen content (0.6) and thickness of the raw skin (0.7). The chromic oxide content of the leathers was also found to increase significantly with the increase in looseness (0.6) and a decrease in the angle of weave of collagen fibres in the raw skin. These correlations tie in with the decrease in looseness and increase in angle of weave exhibited by the skins with age and slaughter weight.

4.3.2. Physical Properties.

4.3.2.1. Softness.

4.3.2.1.1. Phase I Leathers.

The softness of leathers from Phase I were measured by BLC Softness gauge in terms of mm distension. In figures 26(v) and (vi) the mean values and standard differences are shown for the different age and weight groups. Only male skins were seen to vary in softness with age ($p<0.01$ between age group O and 6); the older the skin the less soft it tended to be. However both male and castrate skins became significantly less soft with increasing slaughter weight of the animal. The male skins tended to be softer than the skin from the other two sex groups particularly in the younger, lighter groups.

4.3.2.1.2. Phase II Leathers.

The softness of the various leathers made from Phase II skins did not vary significantly with either the nutritional treatment or slaughter weight group. Mean values are shown in figure 26(vii) and (viii). The leathers from Phase II ranged in softness from 5.3 to 2.4 mm.

4.3.2.1.3. Softness Discussion.

The softness of male and castrate leathers correlated with both the age (-0.57 and -0.75) and weight groups (-0.53 and -0.81 respectively). This negative correlation with age supports the findings reported by Wang (1992). However in this study the female

leather did not show this same relationship with age and the breed effect noted by Wang, which may have, in fact, been due to the sex of the animal. The softness of female leathers in this present study showed a negative correlation with the thickness of the raw skin (-0.53).

Male leather, which showed the greatest range in softness values, was the only sex where softness correlated significantly (0.57) with the compactness of the collagen fibres in corium of the raw skin. Wang (1992) related the softness of the leathers to the compactness and reduced inter-fibre "spaces". It may however be that the softness value is also primarily related to the thickness of the skin.

Figure 26 Chromic oxide content and softness values of leathers.
(Mean values, standard deviation error bars)

(i) Phase I (males) chromic oxide contents of the 4 age groups.
(ii) Phase I (males) chromic oxide contents of the 4 weight groups.
(iii) Phase II chromic oxide contents of the 6 nutritional groups.
(iv) Phase II chromic oxide contents of the 3 weight groups.
(v) Phase I softness values of the 4 age groups.
(vi) Phase I softness values of the 4 weight groups.

(vii) Phase II softness values of the 6 nutritional groups.
(viii) Phase II softness values of the 3 weight groups.

_____

4.3.2.2. Grain Crack, Burst and Distensions.

4.3.2.2.1. Phase I Leathers.

The load taken to crack the grain layers of leathers made from male skins of Phase I increased significantly with the slaughter age of the animal (figure 27(i)). As male leather grain strength increased with age so the leathers also became significantly stronger than leathers from the other two sexes, requiring the maximum mean loading of 619 N to crack the grain of leathers from the oldest age group 6, compared to 425 N and 325 N for castrate and female leathers respectively in this age group. The leathers from castrated animals also tended to increase their grain strength with age, but to a lesser extent than males, while loads required by female leathers did not appear to alter with age. The distension of leathers at grain crack was only seen to vary significantly in the oldest age grouping where male skins produced larger distensions than both the castrate and female skins (figure 27(iii)).

Similar trends were seen in the load at grain crack data when considered on the basis of slaughter weight. Male leathers increased their grain strength significantly with the slaughter weight of the animal (weight groups 1:3 $p<0.01$), requiring the greatest loadings in weight groups 2 and 3 (figure 27(ii)). Castrate leathers were also increased in strength with the slaughter weight of the animal but less steeply. Only castrate leathers had a significant decrease in distension at crack with slaughter weight (figure 27(iv)). Castrate slaughter weights were spread over the greatest range and it was leathers from the heaviest group 4 that produced significantly lower distensions than all the other weight groups (analysis of variance of weight groups 1:4, 2:4 and 3:4 all gave $p<0.01$).

When the loads required to break through or burst the grain of the leathers were considered, unsurprisingly the same trends as described previously for grain crack were also found but at a higher level (figures 27(v) and (vi)). Male leathers continued to increase in strength with increased growth i.e. body mass and age. Female leathers also showed an increase in strength with increased age (age group 0:4 $p<0.10$) but not with weight. Age and weight comparisons of the distensions at grain burst again

showed no age or weight influence for the female and castrate leathers, however male values did increase significantly with both age and weight (figures 27(vii) and(viii)).

4.3.2.2.2. Phase II Leathers.

Figures 28(i-viii) show the results obtained from the grain crack and burst testing of crust leathers from Phase II. The most prominent feature of these results is that leathers made from the skins of animals kept on the high nutritional regime tended to have both higher loads at grain crack and burst and smaller resulting distensions than leathers from animals in the low nutritional groups. The distensions at both grain crack and burst were also seen to be linked to the slaughter weight of the animal, the distension decreasing significantly with increasing weight ($p<0.01$ and $p<0.05$ respectively)(figures 28(iv) and (viii)).

4.3.2.3. Tensile Strength.

4.3.2.3.1. Phase I Leathers.

Tensile strength increased with age for the male leather in both test directions, but in the case of the females only the perpendicular samples showed this increase (figures 29(i) and (v)). The age of the castrate animals had no significant effect on the strength of the leather. Male leathers also showed an increase in tensile strength with increasing slaughter weight for samples taken in both test directions (figure 29(ii) and (iv)), although this increase was only significant for the test samples cut in the perpendicular direction ($p<0.01$).

Little significant difference in the extension values at break was found between the sexes with age, except in age group 4 where the perpendicular male leather samples had higher extensions than the female skins ($p<0.01$) (figure 29(vii)). (It should be noted however that castrate age group 4 contained only one skin). Male leathers do however show increasing extension to break with increasing age. Again, only male leather samples showed a significant increase in extension with weight (figure 29(viii)).

The tensile strength of the leather samples taken parallel to the backbone of the animal were generally greater than those taken perpendicular to the backbone. Conversely the percentage extension of the leather samples at break were generally greater when taken perpendicular to the backbone than in the parallel direction, irrespective of the trial group.

4.3.2.3.2. Phase II Leathers.

The results from the tensile testing of the leather parallel and perpendicular to the backbone of the animal are shown in figures 30(i) to (viii). The only significant differences between the groups was found in the perpendicular tensile strengths compared on a slaughter weight basis where an increase in strength was associated with a decrease in slaughter weight. The extension produced when the force was applied increased inversely with the tensile strength in both directions.

4.3.2.4. Physical Testing Discussion.

The physical properties of leather determine to a large extent the quality of the leather and the mechanical tests were designed to assess how the leather will perform during the manufacture and use of the finished leathergoods. The strength and extensibility of leather is influenced by a number of factors, which include poor curing and processing of the raw material, different types of tannages, sample location (Vos *et al* (1973Vos *et al* (1973); Boccone *et al* (1977);Boccone *et al* (1977); Stephens & Peters (1989)),Stephens & Peters (1989)), the skin's innate properties such as the amount of fibrous material, grain to corium ratio (Russell (1988)Russell (1988); Haines (1974)Haines (1974)) and other structures and discontinuities present such as hair follicles and sweat glands (Hole *et al* (1979))Hole *et al* (1979)).

All the skins in this project were cured under the same conditions and tanned in the same manner so that differences between the varying trial groups were assumed to be due to variations in the properties of the raw materials. By relating the variations in the

physical properties of the leather to the structural and chemical properties of the raw material the significance of changes in animal production methods can be established.

The load and distension at grain crack and break of a leather act as a guide to how the material will perform during the toe lasting process in shoe manufacture, that is when a multi-directional stress is applied. Grain crack is primarily considered a measure of the strength of the grain layer within the tested material.

The load at grain crack and was found to vary with the sex and age of the animal rather than its weight at slaughter. The tendency for male (intact) animals to produce stronger leathers than castrated animals has also been discovered in deer skins (Milnes & Parker (1979)Milnes & Parker (1979)) and cattle hides (Russell *et al* (1977)Russell *et al* (1977)). Russell *et al* (1977) suggested that the greater strength of bull leathers compared to steer (castrated) leathers was associated with the heavier yield of hide per unit carcass mass, linked ultimately to the higher levels of growth hormone secretion in the intact males. This high level of growth hormone would then result in a higher level of protein synthesis in the body. The Dermal-Stomatic ratios (DSR) of the goats, calculated in section 4.1.1., which relate the weight of the green skins to the weight of the slaughtered animal, indicate that male goats also give a greater yield of skin (by weight) for body weight compared with the other two sexes, and that the DSR increased with age (table (12)).

This higher skin yield could be explained in terms of a thicker, denser skin structure. Both the male and castrate skins increase in thickness with age and slaughter weight, however the castrate skins and leather tended to be as thick or thicker than the male counterparts in each of the trial groupings (figure 31). There were, however, differences between the structures of the skins. The compactness and orderliness of the corium fibres in the male skins increased with age and slaughter weight. The grain layer in the male skins was thinner and the grain:corium ratio decreased with age, resulting in a greater proportion of leather being taken up by the load bearing corium layer. These structural changes are similar to those seen by Russell *et al* (1988)Russell *et al* (1988), Wang (1992)Wang (1992) and Haines (1981)Haines (1981). Work carried out by Jenkinson & Nay (1968Jenkinson & Nay (1968) and Everett &

Hannigan (1978)Everett & Hannigan (1978) however found no significant changes in grain layer thickness of cattle hides with either age or sex.

Alternatively the differences between male and castrated animals could be related to the growth parameters of the animals. Castrated animals mature at a slower rate and continue to increase body weight at a greater rate reaching a heavier body weight than intact males (Bonsma (1980))Bonsma (1980)). Therefore, if maturity is considered the point at which growth ceases (Bailey & Robins (1973)Bailey & Robins (1973)), the castrated animals are still actively growing and synthesising new collagen which reduces the overall maturity or stability of the skin collagen population and thus presumably the strength and extensibility of the leathers made from their skins. IMT analysis of castrate skins may have been expected to have reflected the expected relative immaturity of the collagen in the skins compared to male skins in the same age or weight groups. (However, it is doubtful if the method of assessing the age of the animals by their teeth would have been accurate enough). All skins from castrate animals in Phase II were "mature" in terms of R_{10} and R_{30} values and these animals were equivalent to Phase I age group 0. However since the amount of soluble collagen present may have been a better indication of new collagen synthesis (Russell *et al* (1980)Russell *et al* (1980); Bruyn *et al* (1987)Bruyn *et al* (1987)), the hypothesis that strength differences between male and castrates is due to the difference in the levels of immature collagen is not discounted.

The effect of nutritional restriction during the life of the animal produces leather that is stronger and more extensible (Russell *et al* (1980)Russell *et al* (1980); Milnes & Peters (1977)Milnes & Peters (1977)). The effect of nutritional stress on skins and leather could be considered similar to that already discussed between intact and castrated males. Nutritional restriction depresses active growth and increases the proportion of mature to new collagen (Russell *et al* (1980); Bruyn *et al* (1987)). Again this was not evident from the IMT analysis of Phase II skins, but as mentioned earlier it may have been more appropriate to evaluate the soluble collagen content of the skins. The nutritionally restricted goats tended to produce lighter thinner skins with a thinner grain layer and the load at grain crack of the low nutrition groups did tend to be lower than that of the high nutrition animals (figure 28). Walker (1957)Walker (1957) also found

that a low plane of nutrition produced thinner cattle hides, while the age of the animal had little effect.

Peters & Stephens (1989)Peters & Stephens (1989) found a species but not a sex difference in lastometer failure load values from kangaroo leathers. These and other workers found it appropriate to divide lastometer loads by leather thickness. If the values obtained from the grain crack and burst testing of Phase I are "normalised" in this way (i.e. by dividing load at grain crack and burst by the leather sample thickness), then the dramatic rises in male values of load at grain crack and burst in Phase I are lost (figure 31), although male leathers still have the highest values.

Correlation analysis showed high negative correlations between both % nitrogen (total protein) and the thicknesses of the skin with the amount of distension at grain crack and burst obtained for castrated and male skins. A positive correlation between % fat in the skin and the amount of distension was seen for male leathers but a negative coefficient in castrates. Thus as the skins become thicker (with increasing age and weight) so the extensibility of the leather reduces. The amount of fat present may influence the distension by blocking the amount of material normally removed from the grain layer during processing making the fibre structure less open and able to extend, or may just be an indirect factor also interacting with the age/weight of the animal. Bitcover & Everett (1978)

Bitcover & Everett (1978) observed a significant positive correlation between the fat content of bovine leather and the distension at grain crack. In the present study a significant correlation between the fat content of the goat skins and the leather distension at grain crack was not found. However the actual fat content of the leather was not determined. There was no specific degreasing stage during the leather processing of the goat skins. It is possible that differing amounts of the natural fat were lost and different amounts of fat liquor were taken up by the skins, which may have an overriding influence on the physical properties of the leather. Tancous & Schmitt (1967)Tancous & Schmitt (1967) noted that cattle hides that gave low tensile strengths (tested as raw hides), contained greater amounts of fat in the corium fibre structure. The leather made from these hides was also weak due to looseness and high angles of weave of the fibre structure after the fat was removed. Castrated animals in Phase I,

which seem to have significantly higher fat contents in the older, heavier weight groups, may have had a similar disrupted collagen fibre structure in the leather. Conversely a decrease in the number of fat cells in the corium of nutritionally restricted cattle was noted by Bruyn *et al* (1987), which would tend to leave a more compact fibre structure in the leather.

The tensile strength and extension to break of leather have previously been shown to decrease with increased age (and body mass) (Russell *et al* (1977); (1988)). Russell *et al* (1977) explained the decrease in strength found in the cattle hides with age in terms of the "embrittlement" of the collagen fibres due to the increased crosslinks. This trend observed for bovine hides was not seen in the goat leathers from Phase I. The male leathers increased their tensile strength with age in a similar manner found by Wang (1992). In contrast to Russell *et al* (1977) it is contended that this phenomenon is consistent with the collagen becoming more mature and the numbers of cross-linkages between the molecules increasing with increased age. This increase in collagen crosslinks with age could also tend to explain the decrease in flexibility and extension seen in older skins. The same effect of increasing strength with increased crosslinking would tend to occur after periods of restricted weight gain, suggesting that in the case of the male and females active weight gain may not be present in the older, heavier animals and that dietary conditions may also influence the physical properties of leather. However, where there is a relatively high percentage of immature collagen in the overall collagen population, as possibly in the case of the castrated skins where active growth was still taking place, the tensile strength of the leather tends to decrease. Similar nutritional effects to those reported by Russell *et al* (1977)Russell *et al* (1977) were seen in Phase II where the LN and parasite stressed groups of animals tended to produce stronger, less extensible leathers.

The crosslinking process of collagen is considered to be dependent on the physiological rather than the temporal age of the animal (Bailey & Shimokomaki (1971))Bailey & Shimokomaki (1971)). The increase in the number of stable, non-reducible crosslinks between collagen molecules in skin relates to the observed increases in the stability

and tensile strength of the collagen fibres with age by preventing slippage (Bailey & Robins (1973)Bailey & Robins (1973); Harkness (1971Harkness (1971)).

Clark (1986) reported that poor nutrition will result in the formation of smaller collagen fibres but with a lower angle of weave, resulting in a weaker, less interwoven fibre structure. Clark (1986) also states that the maturation of the collagen crosslinks is impaired in animals kept on a low protein diet. The first requirement of the body is for a source of metabolic energy. Only when this requirement is not met by the dietary intake are proteins used for fuel, rather than for the replacement of tissue proteins (Bender (1993)Bender (1993)). The differences reported in the physical properties of skins and leathers from nutritionally stressed animals could be explained by the degree of stress they were exposed to. The effects on skin and leather yields and strength from nutritionally stressed animals have been shown to be reversible if the animals are exposed to a period of high nutrition before slaughter (Bruyn *et al* (1987); Russell *et al* (1988)).

The differences between the results for goats and cattle may in part lie in the structure of the different skins. Goat skins contain a higher proportion of elastin fibres through their structure and the relative grain to corium ratios are larger (Joseph *et al* (1960)). An increased grain to corium ratio, as seen in the goat skins would tend to decrease the physical strength of the skins (for example in the female and castrate animals) along with the angle of weave of the collagen fibres in the corium. Miller & Karmas (1985)Miller & Karmas (1985) investigated age related changes in the collagen ultra structure of bovine corium. These studies showed that the fibre packing and fibre diameter became progressively tighter and larger with increased age suggesting an explanation for their increased resistance to mechanical and chemical damage.

The physical properties of leather have been shown previously (Haines (1974)) and here to be inherently dependent on the architecture of the collagen fibres in the corium, particularly if the mechanical stress is applied in one direction as in tensile testing. The arrangement of collagen fibres in a skin or hide is not uniform. Therefore the fibres have different orientations which vary with the body location because skin performs a variety of functions in different parts of the body and is under different tensions and stresses. Fibre size and packing can also vary. For example in contrasting of skin

taken from flexible (knee, elbow) and non-flexible (thigh, forearm) parts of the body, the collagen fibres in "flexing" skin were smaller and more finely separated than in "non-flexing" skin (Muthiah *et al* (1977Muthiah *et al* (1977)). *In vivo* the skin is under tension, which varies in magnitude and direction in different parts of the body. This conclusion is readily verified by making a round hole in the skin of a cadaver which immediately becomes oval (Marks (1983Marks (1983)).

Figure 27 Load at grain crack, burst and distension values of Phase I leathers. (Mean values, standard deviation error bars)

(i) Load at grain crack values of the 4 age groups.
(ii) Load at grain crack values of the 4 weight groups.
(iii) Distension values at crack of the 4 age groups.
(iv) Distension values at crack of the 4 weight groups.
(v) Load at grain burst values of the 4 age groups.
(vi) Load at grain burst values of the 4 weight groups.

(vii) Distension values at burst of the 4 age groups.
(viii) Distension values at burst of the 4 weight groups.

Figure 28 Load at grain crack, burst and distension values of Phase II leathers. (Mean values, standard deviation error bars)

(i) Load at grain crack values of the 6 nutritional groups.
(ii) Load at grain crack values of the 4 weight groups.
(iii) Distension values at crack of the 6 nutritional groups.
(iv) Distension values at crack of the 4 weight groups.
(v) Load at grain burst values of the 6 nutritional groups.
(vi) Load at grain burst values of the 4 weight groups.

(vii) Distension values at burst of the 6 nutritional groups.
(viii) Distension values at burst of the 4 weight groups.

Figure 29 Tensile strength (TS) and percentage extension values of Phase I leathers (taken parallel and perpendicular to back bone). (Mean values, standard deviation error bars)

(i) Tensile strength (parallel) values of the 4 age groups.
(ii) Tensile strength (parallel) values of the 4 weight groups.
(iii) Extension at break (parallel) values of the 4 age groups.
(iv) Extension at break (parallel) values of the 4 weight groups.
(v) Tensile Strength (perpendicular) values of the 4 age groups.
(vi) Tensile Strength (perpendicular) values of the 4 weight groups.

(vii) Extension at break (perpendicular) values of the 4 age groups.
(viii) Extension at break (perpendicular) values of the 4 weight groups.

Figure 30 Tensile strength (TS) and percentage extension values of Phase II leathers (taken parallel and perpendicular to back bone). (Mean values, standard deviation error bars)

(i) Tensile strength (parallel) values of the 6 nutritional groups.
(ii) Tensile strength (parallel) values of the 4 weight groups.
(iii) Extension at break (parallel) values of the 6 nutritional groups.
(iv) Extension at break (parallel) values of the 4 weight groups.
(v) Tensile strength (perpendicular) values of the 6 nutritional groups.
(vi) Tensile strength (perpendicular) values of the 4 weight groups.

(vii) Extension at break (perpendicular) values of the 6 nutritional groups.
(viii) Extension at break (perpendicular) values of the 4 weight groups.

Figure 31 Load at grain crack and burst values of Phase I leathers normalised for thickness.
(Mean values, standard deviation error bars)

(i) Load at grain crack values of the 4 age groups.
(ii) Load at grain crack values of the 4 weight groups.

(iii) Load at grain burst values of the 4 age groups.
(iv) Load at grain burst values of the 4 weight groups.

Chapter 5 Conclusions

5. Conclusions.

The basic chemical constituents (moisture, fat and nitrogen) of goat skins are influenced by both the age and sex of the animal. Male goat skins have less fat, more protein (nitrogen) and higher moisture contents than female and castrate skins. Fat contents of female and castrate skins increase with age and slaughter weight. Skin fat contents of animals on a high plane of nutrition are greater than those on low nutrition. The fat content of skins are reduced as the parasitic worm burden increases.

Biochemical components (GAG and collagen) showed little variation with the test parameters, a reflection of the early maturing nature of these components in the skin. Practically because of the way the animals were aged, i.e. by dentition, the exact age of the animals were not available. This meant that some of the expected relationships between skin components and age, for example GAGs, were not apparent from the results. However it can be concluded that GAG contents are greatest in castrate skins and skins from animals on a low plane of nutrition.

The weight, age, sex and nutritional conditions all have varying degrees of influence on the thickness of skin. The main influences are the slaughter weight (which is linked to age and nutrition) and sex of the animal. Thickness of skin increases with age and weight. The increase in thickness predominantly occurs in the corium layer of the skin. Increased thickness of skin can affect the strength of the resulting leather. Castrate skins are thicker than equivalent male skins, which in turn are thicker than female skins. Skins from animals on low plane nutrition are thinner than those on a high plane of nutrition.

The physical properties of goat skin leathers are directly related to the thickness of the skin (and weight), the grain to corium ratios and corium structure. The leathers tend to

become stronger and give lower extensions with increasing age and increasing nutritional stress. The physical properties of the leathers are also linked to the sex of the animal with the strongest leathers being obtained from male animals.

The softness of leathers made from the skins is primarily influenced by the sex of the animal and its slaughter weight. Male and skins from light animals produce the softest leathers. Castrate skins produce the firmest leathers. Nutritional conditions (in the range investigated) do not significantly affect the softness of the leathers produced.

The chromic oxide content of leather from male skins is inversely related to the age, weight of the animals and the tensile strength to the subsequent leathers. Leather made from skins of nutritionally restricted animals contains higher levels of chromic oxide than leather from non-restricted animals.

During the production of a piece of leather the material is shaved to the desired thickness from the flesh side i.e. removal of substance is from the corium layer. This operation then alters the grain to corium ratio within the leather. The greater the proportion the grain layer takes up the weaker the leather becomes. Therefore a skin from an extensively produced animal will produce a stronger piece of shaved leather compared to that from an intensively produced animal because of the differences in the relative amounts of grain and corium layers.

If the numbers of female and castrate animals in the general population increases, or more intensive production systems are incorporated in the development schemes for goats, the levels of fat may cause problems during processing. If no degreasing step is used in the manufacturing of leather, levels of 5% fat and above can lead to poor penetration of chemicals and fat spews on the finished leather. Fatty skins have also been linked to the production of weaker leather.

Altering the present systems of goat production in N.E. Brazil will also affect the nature of the goat skins and leathers produced from the region. A move towards intensification will produce younger animals with heavier, thicker, fattier but less mature skins compared with animals of the same slaughter weight reared in extensive systems. The leathers produced from these skins will be weaker than those produced from traditional extensive systems and will affect the manufacture and performance of finished leathergoods.

Chapter 6 Future Work

6. Future Work

It would be of interest to know the possible interrelationships between the raw skin constituents and the structure of leather and its, the leather structure, subsequent effect on physical properties. The present study of Brazilian goat skins, and that by Wang (1992), concentrated on the chemical and physical structure of the raw skins and how they affected the physical properties of leather. For example although the GAG content of the skins was analysed its removal during processing was not. Poor removal of GAG is a reflection of poor opening up of leather which can affect its physical properties.

Some of the expected age related effects were not apparent in this project. It is suggested in any future work that a more accurate method of ageing animals than by dentition be used.

It is suggested that the amount of soluble collagen present in the skins may be a more accurate method of determining the effects of the different parameters on the maturity of the collagen in the skins.

The softness of the leathers were determined using the BLC Softness gauge, it would be interesting to investigate the effect of leather thickness and density on its results.

Relating the physical properties of the leather to those of the fresh/rehydrated skin may produce a useful method of indicating the final leather quality.

Only 5 to 7% of goat skins in many areas of Brazil can be classified as "first quality" skins (Figueiredo *et al* (1982)). The major problem in fully utilising goat skins are defects occurring during the life of the animal. It would be of significant benefit to both the producers and consumers to obtain better quality skins through local animal production and rawstock improvement schemes.

150

APPENDIX I

Appendix I

Appendix I - Experimental dried goat skin - Leather processing method.

151

Process Step	Chemical/Description	Time
Rehydration		
Dirt Soak	Excess water + 1 g/l chloros.	1 hour
Main Soak	Immerse in pH10 liquor. 0.5 g/l Na_2CO_3	leave static overnight
	Break over beam, dry drum for 5 minutes. Reimmerse in same liquor.	leave static overnight
	Break over beam, dry drum for 15 minutes. Reimmerse in same liquor.	leave static overnight
	Break over beam, dry drum for 45 minutes. Reimmerse in new liquor.	
	Drum for approximately 4 hours in liquor (slow speed).	
Unhairing	Paint skins with sulphide solution* (on flesh side) & stack.	leave overnight
	Unhair over beam.	
Lime	Immerse in 500% water, 10% lime and 1% sodium sulphide.	leave overnight, running at slow speed (5 min./hr.)

	Drain, refloat in 2% lime liquor.	leave for 2 days
Rinse	Refloat in excess water. Large float/slow speed.	15 minutes

Experimental dried goat skins - Leather processing methods (continued).

Process Step	Chemical/Description	Time
2nd Rinse	Drain and refloat in excess water. Large Float/slow speed.	15 minutes
Delime	Drain and refloat in 400% water, 2% ammonium chloride.	run for 1 hour
Bate	Drain and refloat 200% water at 35°C, 1% Pancreol 5A.	run for 2 hours
	Scud over beam.	
	Drain and refloat in 200% water at 35°C, 1% Pancreol 5A.	run for 1 hour
	Scud over beam.	
Rinse	Refloat in 100% water.	run for 15 minutes
Pickle	Drain and refloat in 100% water, 10% sodium chloride.	run for 5 minutes
	Add 1% sulphuric acid (diluted 1:10).	until cross section cut is pH 2.5
Tannage	Drain and refloat 300% water, 3% sodium chloride, 1.25% Chromic oxide (33% basic, 25% Cr_2O_3).	run for 30 minutes
	Add 1.25% Chromic oxide (33% basic, 25% Cr_2O_3).	drum until chrome is penetrated (approx 3 hours)
Basification	Add 1% sodium bicarbonate (diluted 1:10). Add slowly until liquor is pH3.6-3.8. Check shrinkage temperature to be 95-100°C.	leave overnight if necessary
	Drain, wash and horse.	

Rinse	leave overnight

Experimental dried goat skins - Leather processing methods (continued).

Process Step	Chemical/Description	Time
Neutralisation	Refloat in 200% water at 35°C.	run for 10 minutes
	- check pH of cut is 6, if not then drain and refloat in 100% water at 35°C, 1% sodium bicarbonate, 1% sodium formate.	run for 30 minutes
Rinse	- check pH of cut at 6, if not then add 1% sodium bicarbonate	run for 30 minutes
	otherwise drain, wash in 200% water at 50°C.	run for 10 minutes
Fatliquoring	Drain and refloat in 100% water at 50°C, 4% Remsynol ESI emulsified 1:3.	run for 45 minutes
	Horse up.	leave for 2 days
	Sam & set, toggle to dry.	until dry
Conditioning	Spray with water, store in plastic for 1 hour and hand stake.	

* sulphide paint solution - 150 g/l sodium sulphide
600 g lime (25-30°Be)
Thicken with lime to 28 seconds
Ford cup 4 (35°Be)

Percentages quoted in the method were based firstly on the weight of the rehydrated skins and then on the weight of the limed skins.

155

The temperature of the water used was room temperature (approximately 15^{o}C) unless otherwise stated.

APPENDIX II

APPENDIX II

158

Experimental data from dried skin and leather analyses of Phase I goats.

Mean values and standard differences (SD)

Abbreviations used in tables:

Slaughter Weight Groups:

1 - Up to 9.9 kg.

2 - 10 to 14.9 kg.

3 - 15 to 19.9 kg.

4 - 20 kg and over.

Age groups:

0 - Up to 15 months.

2 - 15 to 21 months.

4 - 21 to 26 months.

6 - 26 + months.

1.1. Animal Data

Table I - Age Groups

AGE GROUP		n	SLAUGHTER WEIGHT / kg	SD	DRIED SKIN WEIGHT / g	SD	GREEN SKIN WEIGHT / g	SD
MALE	0	15	8.3	0.8	341	188	971	132
	2	8	12.6	2.3	543	80	1513	257
	4	4	13.8	1.8	685	90	1850	310
	6	2	18.8	1.1	895	149	2470	523
CASTRATE	0	15	9.1	0.2	428	174	1055	146
	2	11	12.4	3.4	419	101	1360	241
	4	1	10.4	-	450	-	1200	-
	6	8	20.8	6.8	955	269	2338	602
FEMALE	0	4	8.2	1.3	395	124	850	192
	2	10	12.9	2.5	521	151	1510	228
	4	7	14.9	2.7	690	203	1600	370
	6	11	15.0	3.0	616	160	1636	345

Table II - Slaughter Weight Groups

SLAUGHTER WEIGHT GROUP		n	DRIED SKIN WEIGHT / g	SD	GREEN SKIN WEIGHT / g	SD
MALE	1	16	351	186	994	160
	2	8	560	82	1556	257
	3	5	778	152	2128	479
CASTRATE	1	17	414	206	1068	176
	2	8	413	98	1325	190
	3	7	743	246	1883	487
	4	3	1217	43	2933	116
FEMALE	1	5	390	105	980	268
	2	16	535	154	1369	182
	3	11	718	142	1900	184

1.2. Chemical analysis of skins

Table III - Age Groups

AGE GROUP		n	MOISTURE / %	SD	FAT / %	SD	NITROGEN / %	SD
MALE	0	10	15.21	0.77	2.47	0.77	16.69	0.77
	2	8	15.38	0.59	2.40	1.22	16.56	0.14
	4	4	15.45	0.58	1.64	0.28	16.46	0.32
	6	2	15.34	0.03	2.17	0.20	16.46	0.02
CASTRATE	0	10	12.86	0.25	2.18	0.44	15.02	0.29
	2	10	13.57	0.63	2.24	1.42	15.28	0.18
	4	1	13.06	-	3.60	-	15.04	-
	6	8	12.83	0.31	4.65	2.38	15.41	0.16
FEMALE	0	4	13.49	1.32	2.67	0.56	15.73	0.90
	2	10	14.41	0.73	2.70	1.90	16.35	0.44
	4	7	14.29	0.26	3.29	1.08	15.17	0.50
	6	10	14.55	2.69	2.52	1.03	15.40	0.40

Table IV - Slaughter Weight Groups

SLAUGHTER WEIGHT GROUP		n	MOISTURE / %	SD	FAT / %	SD	NITROGEN / %	SD
MALE	1	11	15.22	0.76	2.45	0.76	16.68	0.76
	2	8	15.26	0.54	2.35	1.22	16.52	0.25
	3	5	15.64	0.47	1.81	0.42	16.49	0.08
CASTRATE	1	11	13.17	0.53	2.13	0.33	15.08	0.31
	2	8	12.98	0.40	2.51	1.61	15.15	0.24
	3	7	13.34	0.73	3.07	1.81	15.30	0.14
	4	3	12.93	0.42	6.16	2.17	15.46	0.19
FEMALE	1	5	13.90	1.52	2.28	0.78	15.81	0.89
	2	15	14.46	0.48	2.18	0.72	15.84	0.80
	3	11	14.30	0.30	3.88	1.61	15.41	0.53

1.3. Biochemical Analysis of Skins

Table V - Age Groups

AGE GROUP		n	COLLAGEN / %	SD	GAG (on collagen) / %	SD
MALE	0	10	61.11	2.12	0.64	0.15
	2	8	57.54	2.46	0.94	0.08
	4	4	57.05	1.94	0.62	0.16
	6	2	55.54	0.03	0.48	0.16
CASTRATE	0	10	52.74	5.48	1.00	0.14
	2	10	60.29	3.60	0.90	0.16
	4	1	62.11	-	0.95	-
	6	8	63.17	8.41	0.99	0.14
FEMALE	0	4	60.85	2.76	0.72	0.12
	2	10	68.88	0.87	0.89	0.02
	4	7	63.55	4.31	0.75	0.15
	6	10	62.61	2.82	0.72	0.13

Table VI - Slaughter Weight Groups

SLAUGHTER WEIGHT GROUP		n	COLLAGEN / %	SD	GAG (on collagen) / %	SD
MALE	1	11	60.54	2.38	0.70	0.20
	2	8	57.06	2.18	0.78	0.23
	3	5	56.84	2.38	0.62	0.14
CASTRATE	1	11	55.72	7.22	0.98	0.17
	2	8	56.43	6.11	0.90	0.05
	3	7	66.77	9.02	0.96	0.07
	4	3	58.10	3.33	1.04	0.03
FEMALE	1	5	62.07	4.66	0.77	0.14
	2	15	67.26	3.43	0.83	0.12
	3	11	62.87	2.94	0.73	0.12

1.4. Histological Analysis of Skins.

1.4.1. Skin Layer Thicknesses.

Table VII - Age Groups

AGE GROUP		n	TOTAL SKIN THICKNESS / μm	SD	GRAIN LAYER THICKNESS / μm	SD	HAIR FOLLICLE DEPTH / μm	SD
MALE	0	10	751	167	177	44	321	88
	2	8	1021	184	219	50	474	96
	4	4	1139	254	193	35	502	99
	6	2	1265	61	263	10	447	21
CASTRATE	0	10	1147	318	278	71	573	109
	2	10	1220	243	266	61	587	111
	4	1	852	-	212	-	464	-
	6	8	1445	308	327	61	656	123
FEMALE	0	4	846	164	200	49	355	85
	2	10	918	198	219	29	592	67
	4	7	848	182	236	38	411	79
	6	10	840	151	207	28	373	74

Table VIII - Slaughter Weight Groups

SLAUGHTER WEIGHT GROUP		n	TOTAL SKIN THICKNESS / μm	SD	GRAIN LAYER THICKNESS / μm	SD	HAIR FOLLICLE DEPTH / μm	SD
MALE	1	11	754	159	178	42	327	87
	2	8	1034	183	218	45	486	87
	3	5	1240	139	224	56	481	98
CASTRATE	1	11	1179	350	289	80	592	121
	2	8	1132	176	250	34	544	95
	3	7	1280	294	291	79	610	121
	4	3	1646	117	341	18	714	66
FEMALE	1	5	759	64	181	15	316	46
	2	15	873	143	217	28	384	61
	3	11	907	223	232	38	418	81

_ _

1.4.2. Corium Fibre Structure.

Table IX - Age Groups

AGE GROUP		n	COMPACTNESS	SD	ORDERLINESS	SD	ANGLE OF WEAVE	SD
MALE	0	10	1.85	0.57	1.52	0.41	1.77	0.63
	2	8	1.56	0.50	1.63	0.44	2.31	0.44
	4	4	1.50	0.25	1.58	0.52	3.17	0.14
	6	2	1.00	0.00	1.00	0.00	3.50	0.00
CASTRATE	0	10	1.72	0.44	1.22	0.44	2.11	0.33
	2	10	1.20	0.48	1.40	0.46	3.20	0.63
	4	1	1.00	-	1.00	-	4.00	-
	6	8	1.36	0.63	1.43	0.53	2.93	0.61
FEMALE	0	4	1.25	0.50	1.25	0.50	2.00	0.00
	2	10	1.40	0.51	1.30	0.50	2.88	0.21
	4	7	1.18	0.31	1.43	0.53	3.14	0.24
	6	10	1.66	0.48	1.84	0.32	3.09	0.42

Table X - Slaughter Weight Groups

SLAUGHTER WEIGHT GROUP		n	COMPACTNESS	SD	ORDERLINESS	SD	ANGLE OF WEAVE	SD
MALE	1	11	1.79	0.59	1.56	0.41	1.83	0.64
	2	8	1.75	0.38	1.57	0.53	2.50	0.63
	3	5	1.15	0.22	1.35	0.34	3.00	0.59
CASTRATE	1	11	1.60	0.57	1.25	0.42	2.55	0.69
	2	8	1.31	0.46	1.38	0.52	2.83	0.99
	3	7	1.36	0.63	1.36	0.48	3.00	0.58
	4	3	1.00	0.00	1.50	0.71	3.00	0.00
FEMALE	1	5	1.20	0.44	1.20	0.45	2.40	0.55
	2	15	1.47	0.47	1.51	0.49	2.88	0.38
	3	11	1.45	0.52	1.64	0.50	3.16	0.36

Angle of weave: 1 = low 4 = high
Orderliness: 1 = orderly 2 = disordered

_ _

Compactness: 1 = compact 3 = loose

1.5. Hydrothermal Isometric Tension (IMT) Analysis of Dried Skins

1.5.1. Relaxation of Tension After 10 (R_{10}) and 30 (R_{30}) Minutes.

Table XI - Male Age Groups

TREATMENT	n	R_{10} / %	SD	R_{30} / %	SD
0	10	10.7	11.1	16.2	15.7
2	8	6.3	10.9	9.3	16.0
4	4	0.0	0.00	0.0	0.00
6	2	18.8	0.60	27.0	0.10

Table XII - Male Slaughter Weight Groups

SLAUGHTER WEIGHT GROUP	n	R_{10} / %	SD	R_{30} / %	SD
1	11	9.7	10.9	14.7	15.7
2	8	6.3	10.9	9.3	16.0
3	5	7.5	10.3	10.8	14.8

1.5.2. Z values and Maximum Stress (σm)

Table XIII - Male Age Groups

TREATMENT	n	Z	SD	σm / KPa	SD
0	10	0.36	0.21	304.1	42.2
2	8	0.16	0.20	285.5	81.4
4	4	0.00	0.00	291.4	15.7
6	2	0.31	0.02	261.0	10.8

Table XIV - Male Slaughter Weight Groups

SLAUGHTER WEIGHT GROUP	n	Z	SD	σm / KPa	SD
1	11	0.33	0.23	311.0	46.1
2	8	0.16	0.20	276.6	72.6
3	5	0.15	0.18	276.6	18.6

1.6. Physical Testing Results of Leathers.

1.6.1. Lastometer Results.

1.6.1.1. Load at Grain Crack and Burst.

Table XV - Age Groups

AGE GROUP		n	LOAD AT GRAIN CRACK / Nmm^{-1}	SD	LOAD AT BREAK / Nmm^{-1}	SD
MALE	0	10	303	63	388	66
	2	8	382	48	514	144
	4	4	538	144	661	152
	6	2	619	103	818	34
CASTRATE	0	10	311	41	442	54
	2	10	348	70	489	120
	4	1	233	-	430	-
	6	8	425	51	568	96
FEMALE	0	4	269	28	361	9
	2	10	368	54	478	88
	4	7	328	29	548	72
	6	10	325	63	480	45

Table XVI - Slaughter Weight Groups

SLAUGHTER WEIGHT GROUP		n	LOAD AT GRAIN CRACK / Nmm^{-1}	SD	LOAD AT BREAK / Nmm^{-1}	SD
MALE	1	11	309	62	395	67
	2	8	424	115	518	128
	3	5	537	134	759	132
CASTRATE	1	11	300	42	424	62
	2	8	348	60	497	67
	3	7	410	78	561	131
	4	3	448	33	575	140
FEMALE	1	5	306	46	418	77
	2	15	324	60	481	78
	3	11	356	57	525	68

1.6.1.2. Distension at Grain Crack and Burst

Table XVII - Age Groups

AGE GROUP		n	DISTENSION AT GRAIN CRACK / mm	SD	DISTENSION AT BREAK / mm	SD
MALE	0	10	10.45	0.89	11.43	0.79
	2	8	10.50	0.88	12.13	1.27
	4	4	10.78	0.44	12.40	0.92
	6	2	11.70	1.70	14.15	0.64
CASTRATE	0	10	9.49	0.44	11.10	0.66
	2	11	9.48	0.38	11.28	0.79
	4	1	9.40	-	12.00	-
	6	8	9.49	0.91	11.29	1.36
FEMALE	0	4	9.40	1.51	11.07	1.37
	2	10	9.71	0.91	11.18	0.96
	4	7	9.44	1.59	11.84	0.98
	6	10	8.94	0.48	11.22	0.66

Table XVIII - Slaughter Weight Groups

SLAUGHTER WEIGHT GROUP		n	DISTENSION AT GRAIN CRACK / mm	SD	DISTENSION AT BREAK / mm	SD
MALE	1	11	10.35	0.90	11.37	0.76
	2	8	10.78	0.74	12.13	0.93
	3	5	10.98	1.14	13.42	1.30
CASTRATE	1	11	9.45	0.40	11.01	0.60
	2	8	9.60	0.48	11.35	0.59
	3	7	9.92	0.54	12.00	1.18
	4	3	8.57	0.45	10.47	1.51
FEMALE	1	5	9.40	1.22	10.95	1.14
	2	15	9.44	1.18	11.37	1.04
	3	11	9.19	0.72	11.04	0.66

_ _

1.6.2. Tensile Strength and Extension at Break.

1.6.2.1. Tensile Strength.

Table XIX - Age Groups

AGE GROUP		n	TENSILE STRENGTH (⊥) / Nmm^{-2}	SD	TENSILE STRENGTH (|) / Nmm^{-2}	SD
MALE	0	10	22.44	5.2	40.75	5.2
	2	8	30.65	5.1	39.93	9.1
	4	4	33.58	9.4	48.15	6.6
	6	2	31.45	4.9	50.00	4.1
CASTRATE	0	10	27.17	5.4	42.60	10.1
	2	10	28.76	6.5	43.30	11.1
	4	1	31.20	-	29.80	-
	6	8	26.68	2.9	42.40	7.6
FEMALE	0	4	22.67	3.8	40.70	5.4
	2	10	24.21	4.2	39.30	5.1
	4	7	31.10	4.1	37.90	4.7
	6	10	28.88	4.6	39.80	6.9

Table XX - Slaughter Weight Groups

SLAUGHTER WEIGHT GROUP		n	TENSILE STRENGTH (⊥) / Nmm^{-2}	SD	TENSILE STRENGTH (|) / Nmm^{-2}	SD
MALE	1	11	23.39	5.8	41.40	5.3
	2	8	29.23	3.7	39.86	9.3
	3	5	35.14	8.4	49.02	5.4
CASTRATE	1	11	26.45	3.9	39.81	9.6
	2	8	30.53	7.2	42.16	12.4
	3	7	26.67	4.8	44.82	8.6
	4	3	26.90	3.4	47.23	6.8
FEMALE	1	5	26.11	5.0	41.24	4.0
	2	15	27.55	5.2	39.89	6.2
	3	11	26.89	5.4	37.87	5.2

_ _

1.6.2.2. Extension at Break.

Table XXI - Age Groups

AGE GROUP		n	EXTENSION AT BREAK (⊥) / %	SD	EXTENSION AT BREAK (|) / %	SD
MALE	0	10	114.2	19.9	63.7	7.0
	2	8	118.5	15.8	80.0	19.2
	4	4	133.5	9.8	77.6	8.6
	6	2	142.8	17.4	77.5	10.6
CASTRATE	0	10	120.6	21.5	73.9	12.0
	2	10	113.9	25.3	76.4	14.5
	4	1	87.0	-	90.0	-
	6	8	126.1	31.7	71.8	12.4
FEMALE	0	4	106.0	9.2	65.7	13.0
	2	10	104.2	12.7	66.6	14.7
	4	7	99.6	11.4	72.4	5.6
	6	10	110.8	22.2	70.3	11.1

Table XXII - Slaughter Weight Groups

SLAUGHTER WEIGHT GROUP		n	EXTENSION AT BREAK (⊥) / %	SD	EXTENSION AT BREAK (|) / %	SD
MALE	1	11	114.5	18.9	63.2	6.6
	2	8	124.4	19.0	77.6	14.7
	3	5	130.9	14.5	85.4	13.6
CASTRATE	1	11	111.6	22.9	73.5	11.9
	2	8	121.6	31.7	78.3	11.9
	3	7	124.8	33.1	78.2	17.1
	4	3	124.0	4.3	65.3	9.7
FEMALE	1	5	108.8	17.4	68.5	12.8
	2	15	100.5	9.7	64.4	10.0
	3	11	111.7	21.0	75.3	10.5

1.7. Softness and Chromic Oxide (Cr_2O_3) Content of Leathers

Table XXIII - Age Groups

AGE GROUP		n	SOFTNESS / mm	SD	Cr_2O_3 / %	SD
MALE	0	10	4.37	0.51	4.46	0.57
	2	8	3.47	0.63	3.44	0.32
	4	4	3.08	0.44	3.12	0.08
	6	2	3.35	0.21	3.35	0.08
CASTRATE	0	10	2.82	0.41	-	
	2	10	2.63	0.51	-	
	4	1	3.00	-	-	
	6	8	2.02	0.40	-	
FEMALE	0	4	2.98	1.02	-	
	2	10	2.92	0.82	-	
	4	7	2.67	0.22	-	
	6	10	3.11	0.48	-	

Table XXIV - Slaughter Weight Groups

SLAUGHTER WEIGHT GROUP		n	SOFTNESS / mm	SD	Cr_2O_3 / %	SD
MALE	1	11	4.26	0.60	4.28	0.68
	2	8	3.49	0.59	3.39	0.31
	3	5	3.12	0.47	3.22	0.14
CASTRATE	1	11	2.88	0.40	-	
	2	8	2.61	0.40	-	
	3	7	2.17	0.56	-	
	4	3	1.78	0.16	-	
FEMALE	1	5	3.09	0.82	-	
	2	15	2.98	0.76	-	
	3	11	2.84	0.51	-	

APPENDIX III

APPENDIX III

172

Experimental data from skin and leather analyses of Phase II goats.

Mean values and standard differences (SD)

Abbreviations used in tables:

Nutritional Treatments:

- LN - Control group on low nutritional regime.
- HN - Control group on high nutrition regime.
- LNLW - Low nutritional group with low worm burden.
- LNHW - Low nutritional group with high worm burden.
- HNLW - High nutritional group with low worm burden.
- HNHW - High nutritional group with high worm burden.

Slaughter Weight Groups:

- 1 - Up to 9.9 kg.
- 2 - 10 to 14.9 kg.
- 3 - 15 to 19.9 kg.
- 4 - 20 kg and over.

_ _

1.1. Animal Data

Table XXV - Nutritional Treatment Groups

TREATMENT	n	SLAUGHTER WEIGHT / kg	SD	DRIED SKIN WEIGHT / g	SD	PERCENTAGE DRIED SKIN* / %	SD
LN	6	19.65	2.56	618.3	103.1	3.14	0.26
LNLW	11	15.72	3.66	537.3	130.7	3.49	0.76
LNHW	10	15.29	1.83	486.4	76.0	3.20	0.51
HN	7	22.33	3.56	636.6	123.0	2.85	0.31
HNLW	11	19.89	4.49	623.0	142.6	3.19	0.69
HNHW	13	18.47	4.54	586.2	149.6	3.26	0.75

Table XXVI - Slaughter Weight Groups

SLAUGHTER WEIGHT GROUP	n	DRIED SKIN WEIGHT / g	SD	PERCENTAGE DRIED SKIN* / %	SD
2	9	430.0	57.8	3.63	0.55
3	30	545.3	113.1	3.24	0.72
4	19	686.6	82.6	2.99	0.35

* - ratio of dried skin weight to slaughter weight.

1.2. Chemical Analysis of Skins.

Table XXVII - Nutritional Treatment Groups

TREATMENT	n	MOISTURE / %	SD	FAT / %	SD	NITROGEN / %	SD
LN	6	11.73	0.71	5.14	1.49	14.95	0.10
LNLW	11	11.85	1.16	5.36	2.52	14.94	0.40
LNHW	11	11.43	1.26	5.95	3.18	15.11	0.40
HN	7	10.59	1.08	10.69	4.66	14.95	0.40
HNLW	11	11.52	1.33	7.75	4.78	14.91	0.33
HNHW	13	11.82	1.77	7.89	6.81	14.87	0.29

Table XXVIII - Slaughter Weight Groups

SLAUGHTER WEIGHT GROUP	n	MOISTURE / %	SD	FAT / %	SD	NITROGEN / %	SD
2	9	12.01	1.47	4.51	3.03	14.87	0.25
3	30	11.57	1.31	6.47	4.27	15.02	0.38
4	20	11.26	1.25	9.16	5.19	14.89	0.270

1.3. Biochemical Analysis of Skins.

Table XXIX - Nutritional Treatment Groups

TREATMENT	n	COLLAGEN / %	SD	GAG (on collagen) / %	SD
LN	6	52.82	7.57	0.73	0.11
LNLW	11	53.33	6.10	0.79	0.14
LNHW	11	59.32	5.61	0.80	0.10
HN	7	59.53	8.84	0.65	0.11
HNLW	11	57.52	6.14	0.72	0.11
HNHW	13	55.52	7.32	0.73	0.10

Table XXX - Slaughter Weight Groups

SLAUGHTER WEIGHT GROUP	n	COLLAGEN / %	SD	GAG (on collagen) / %	SD
2	9	55.45	6.24	0.85	0.09
3	30	56.35	6.57	0.76	0.09
4	20	57.05	8.05	0.67	0.12

1.4. Histological Analysis of Skins.

1.4.1. Skin Layer Thicknesses.

Table XXXI - Nutritional Treatment Groups

TREATMENT	n	TOTAL SKIN THICKNESS / μm	SD	GRAIN LAYER THICKNESS / μm	SD	HAIR FOLLICLE DEPTH / μm	SD
LN	6	382	56.1	108	15.2	203	36.0
LNLW	11	379	100.8	102	21.6	214	36.2
LNHW	11	385	105.5	98	18.9	192	35.2
HN	7	485	78.3	115	11.4	251	39.2
HNLW	11	495	120.7	110	13.9	231	50.1
HNHW	13	452	116.5	107	16.2	217	39.7

Table XXXII - Slaughter Weight Groups

SLAUGHTER WEIGHT GROUP	n	TOTAL SKIN THICKNESS / μm	SD	GRAIN LAYER THICKNESS / μm	SD	HAIR FOLLICLE DEPTH / μm	SD
2	9	350	75.0	97	20.4	254	33.0
3	30	420	94.8	107	13.1	307	48.5
4	20	483	123.0	108	12.5	375	43.9

1.4.2. Calculated Percentage Thickness of Total Skin Thickness.

Table XXXIII - Nutritional Treatment Groups

TREATMENT	n	GRAIN LAYER / %	SD	HAIR FOLLICLE DEPTH / %	SD
LN	6	28.3	2.94	53.0	3.20
LNLW	11	24.1	4.61	51.7	6.93
LNHW	11	27.5	3.95	57.6	7.40
HN	7	24.4	3.51	49.5	2.35
HNLW	11	22.9	3.78	47.3	6.23
HNHW	13	26.0	4.72	51.3	9.77

Table XXXIV - Slaughter Weight Groups

SLAUGHTER WEIGHT GROUP	n	GRAIN LAYER / %	SD	HAIR FOLLICLE DEPTH / %	SD
2	9	27.8	4.62	55.6	9.45
3	30	25.9	3.67	52.0	7.34
4	20	23.4	4.56	49.2	6.53

_ _

1.4.3. Corium Fibre Structure.

Table XXXV - Nutritional Treatment Groups

TREATMENT	n	ANGLE OF WEAVE	SD	ORDERLINESS	SD	COMPACTNESS	SD
LN	6	1.58	0.49	1.83	0.27	2.25	0.27
LNLW	11	1.93	0.43	1.71	0.43	1.85	0.46
LNHW	11	1.68	0.73	1.77	0.33	2.32	0.73
HN	7	1.29	0.26	1.86	0.34	2.21	0.40
HNLW	11	2.25	1.17	1.57	0.47	2.08	0.47
HNHW	13	1.80	0.79	1.71	0.47	2.30	0.72

Table XXXVI - Slaughter Weight Groups

SLAUGHTER WEIGHT GROUP	n	ANGLE OF WEAVE	SD	ORDERLINESS	SD	COMPACTNESS	SD
2	9	1.62	0.36	1.71	0.36	2.31	0.39
3	30	1.83	0.82	1.65	0.44	2.11	0.71
4	20	1.83	0.83	1.86	0.35	2.18	0.39

Angle of weave: 1 = low 4 = high
Orderliness: 1 = orderly 2 = disordered
Compactness: 1 = compact 3 = loose

1.5. Hydrothermal Isometric Tension (IMT) Analysis of Dried Skins

1.5.1. Relaxation of Tension After 10 (R_{10}) and 30 (R_{30}) Minutes.

Table XXXVII - Nutritional Treatment Groups

TREATMENT	n	R_{10} / %	SD	R_{30} / %	SD
LN	6	0.70	0.88	1.72	2.03
LNLW	11	0.06	0.93	2.10	2.75
LNHW	11	1.92	3.32	4.14	7.00
HN	7	0.68	0.82	2.30	2.73
HNLW	11	1.63	2.12	4.28	5.61
HNHW	13	1.62	2.24	4.40	6.67

Table XXXVIII - Slaughter Weight Groups

SLAUGHTER WEIGHT GROUP	n	R_{10} / %	SD	R_{30} / %	SD
2	9	1.94	3.36	4.40	6.15
3	30	1.24	1.81	3.09	4.71
4	20	1.05	1.74	3.36	5.59

1.5.2. Z values and Maximum Stress (σm)

Table XXXIX - Nutritional Treatment Groups

TREATMENT	n	Z	SD	σm / KPa	SD
LN	6	0.30	0.34	190.9	37.3
LNLW	11	0.35	0.40	201.6	43.2
LNHW	11	0.23	0.30	213.5	62.8
HN	7	0.51	0.37	149.5	20.6
HNLW	11	0.32	0.30	180.6	79.5
HNHW	13	0.32	0.32	191.3	41.2

Table XL - Slaughter Weight Groups

SLAUGHTER WEIGHT GROUP	n	Z	SD	σm / KPa	SD
2	9	0.27	0.33	217.8	45.9
3	30	0.33	0.33	198.2	73.6
4	20	0.35	0.36	175.6	36.9

1.6. Physical Testing Results of Leathers.

1.6.1. Lastometer Results.

1.6.1.1. Load at Grain Crack and Burst.

Table XLI - Nutritional Treatment Groups

TREATMENT	n	LOAD AT GRAIN CRACK / N	SD	LOAD AT BREAK / N	SD
LN	6	297	93.8	335	95.3
LNLW	11	277	78.6	291	74.0
LNHW	11	272	79.3	294	93.2
HN	7	320	43.7	361	60.6
HNLW	11	337	73.3	354	93.9
HNHW	13	306	48.0	351	71.0

Table XLII - Slaughter Weight Groups

SLAUGHTER WEIGHT GROUP	n	LOAD AT GRAIN CRACK / N	SD	LOAD AT BREAK / N	SD
2	9	273	43.5	282	45.3
3	30	295	74.5	318	80.0
4	20	323	72.4	367	90.0

1.6.1.2. Distension at Grain Crack and Burst.

Table XLIII - Nutritional Treatment Groups

TREATMENT	n	DISTENSION AT GRAIN CRACK / mm	SD	DISTENSION AT BREAK / mm	SD
LN	6	13.22	3.50	14.27	3.45
LNLW	11	13.95	2.98	14.44	3.02
LNHW	11	16.17	3.28	17.06	3.32
HN	7	12.11	2.41	13.16	2.67
HNLW	11	10.68	1.66	11.06	1.79
HNHW	13	12.30	2.96	13.29	3.06

Table XLIV - Slaughter Weight Groups

SLAUGHTER WEIGHT GROUP	n	DISTENSION AT GRAIN CRACK / mm	SD	DISTENSION AT BREAK / mm	SD
2	9	16.92	2.04	17.32	2.01
3	30	13.26	2.63	14.01	2.85
4	20	11.15	3.00	17.12	3.40

1.6.1.3. Load at Grain Crack and Burst corrected for Thickness.

Table XLV - Nutritional Treatment Groups

TREATMENT	n	LOAD AT GRAIN CRACK / Nmm^{-1}	SD	LOAD AT BREAK / Nmm^{-1}	SD
LN	6	340.9	62.2	383.0	58.6
LNLW	11	332.9	83.9	395.7	98.3
LNHW	11	379.7	104.8	414.0	106.4
HN	7	347.7	91.1	398.0	105.9
HNLW	11	314.9	83.6	330.6	98.6
HNHW	13	320.2	72.9	365.9	86.7

Table XLVI - Slaughter Weight Groups

SLAUGHTER WEIGHT GROUP	n	LOAD AT GRAIN CRACK / Nmm^{-1}	SD	LOAD AT BREAK / Nmm^{-1}	SD
2	9	404.1	81.2	416.8	79.5
3	30	334.4	83.3	359.7	100.5
4	20	307.1	73.3	354.2	97.4

1.6.2. Tensile Strength and Extension at Break.

1.6.2.1. Tensile Strength.

Table XLVII - Nutritional Treatment Groups

TREATMENT	n	TENSILE STRENGTH (⊥) / Nmm^{-2}	SD	TENSILE STRENGTH (∣) / Nmm^{-2}	SD
LN	6	26.3	7.0	31.7	3.4
LNLW	11	23.7	5.7	30.3	5.6
LNHW	11	25.1	7.4	30.7	7.1
HN	7	21.0	5.8	25.8	11.1
HNLW	11	23.7	6.7	26.8	8.5
HNHW	13	24.2	6.2	31.2	7.1

Table XLVIII - Slaughter Weight Groups

SLAUGHTER WEIGHT GROUP	n	TENSILE STRENGTH (⊥) / Nmm^{-2}	SD	TENSILE STRENGTH (∣) / Nmm^{-2}	SD
2	9	27.8	8.0	32.9	6.3
3	30	24.5	5.4	29.7	6.7
4	20	21.4	5.9	28.0	8.5

1.6.2.2. Extension at Break.

Table XLIX - Nutritional Treatment Groups

TREATMENT	n	EXTENSION AT BREAK (⊥) / %	SD	EXTENSION AT BREAK (∣) / %	SD
LN	6	106.0	14.7	94.7	9.9
LNLW	11	101.1	17.9	93.1	13.4
LNHW	11	106.6	17.2	91.9	10.0
HN	7	109.7	15.6	101.6	10.7
HNLW	11	111.5	15.6	103.6	9.7
HNHW	13	100.8	13.0	97.3	13.1

Table L - Slaughter Weight Groups

SLAUGHTER WEIGHT GROUP	n	EXTENSION AT BREAK (⊥) / %	SD	EXTENSION AT BREAK (|) / %	SD
2	9	99.3	4.8	72.7	4.5
3	30	106.0	2.7	89.2	18.5
4	20	107.6	3.9	92.9	16.8

1.7. Softness and Chromic Oxide (Cr_2O_3) Content of Leathers

Table LI - Nutritional Treatment Groups

TREATMENT	n	SOFTNESS / mm	SD	Cr_2O_3 / %	SD
LN	6	3.77	0.85	4.27	0.56
LNLW	11	4.44	0.46	4.89	0.36
LNHW	11	4.12	0.48	4.78	0.53
HN	7	3.99	0.70	3.63	0.42
HNLW	11	4.28	0.43	4.62	0.70
HNHW	13	4.19	0.66	4.39	0.69

Table LII - Slaughter Weight Groups

SLAUGHTER WEIGHT GROUP	n	SOFTNESS / mm	SD	Cr_2O_3 / %	SD
2	9	4.09	0.55	4.82	0.39
3	30	4.21	0.62	4.56	0.65
4	20	4.25	0.61	4.22	0.74

182

APPENDIX IV

Appendix IV

183

Statistical methods used during analysis of experimental data:

1. MEAN $x = \frac{\Sigma x}{n}$ where x = sample value
   n = number of values

2. SAMPLE STANDARD DEVIATION (σ_{n-1})

$$\sigma_{n-1} = \sqrt{\frac{\Sigma x^2 - \frac{(\Sigma x)^2}{n}}{n-1}}$$

3. SIMPLE LINEAR REGRESSION, CORRELATION and ANALYSIS OF VARIANCE procedures were carried out using the statistical graphics system STATGRAPHICS (Version 5, STSC Inc.).

   i. SIMPLE LINEAR REGRESSION - This procedure was used to relate a dependent variable to an independent variable by minimising the sum of the squares of the residual of the fitted line y = a + bx.

   ii. CORRELATION ANALYSIS - This procedure produces a matrix of correlation coefficients (r) for a set of values. These correlation coefficients provide a measure of the linear association between the two variables. The coefficient values fall between -1 and +1, a positive value indicates that the variables vary in the same direction, a negative correlation that the variables vary in the opposite direction.

iii. ANALYSIS OF VARIANCE (ANOVA) - This procedure was used to determine how much of the variation seen in the experimental results was caused by population differences and how much was due to random variability. The procedure assumes the data follows a normal distribution.

Analysis of variance indicates that the populations from which samples are taken do not have the same means, but does not indicate which population means actually differ. By using SCHREFFE'S MULTIPLE COMPARISON METHOD all possible comparisons of population means can be undertaken indicating which population means differ significantly.

All statistical methods used are described in Pollard (1979).

The following tables contain results from the analysis of variance between the different groups of experimental data produced in Phases I and II.

Abbreviations used in tables 1.1 - 1.11 (Phase I):

Slaughter Weight Groups:

1 - Up to 9.9 kg.
2 - 10 to 14.9 kg.
3 - 15 to 19.9 kg.
4 - 20 kg and over.

Age groups:

0 - Up to 15 months.
2 - 15 to 21 months.
4 - 21 to 26 months.
6 - 26 + months.

Sex groups:

M - Males.

C - Castrates.

F - Females.

Abbreviations used in tables 2.1 - 2.6 (Phase II):

Nutritional Treatments:

1 - LN - Control group on low nutritional regime.
2 - HN - Control group on high nutrition regime.
3 - LNLW - Low nutritional group with low worm burden.
4 - HNHW - High nutritional group with high worm burden.
5 - HNLW - High nutritional group with low worm burden.
6 - LNHW - Low nutritional group with high worm burden.

Slaughter Weight Groups:

1 - Up to 9.9 kg.
2 - 10 to 14.9 kg.
3 - 15 to 19.9 kg.
4 - 20 kg and over.

Statistical Abbreviations:

NS - Not significant
X - Significant at the 90% level ($p<0.10$)
XX - Significant at the 95% level ($p<0.05$)
XXX - Significant at the 99% level ($p<0.01$)

192

References

192

References

ALLAN C.J., HOLST P.J. & PERVEZ M. (1987) - Pretanning factors affecting the aesthetic quality of Australian goat skins. In 19th IULTCS Congress Proceedings, Melbourne. Pgs. 350-353.

ADEGBOYE J.O.D., OKEZIE N.O. and Aging M.I. (1984) An Estimation of the Physical robustness of the skin of the Nigerian Goat - *Capra Hircus.* J. of Leather Res. 2(2) 26-30.

ALEXANDER K.T.W., HAINES B.M., SHIRLEY S.G. & SYKES R.L. (1988) - Natural and artificial ageing of sheepskin collagen and its importance in leather manufacture. J. Soc. of Leather Tech. & Chem. 72(5)170-176.

ALEXANDER K.T.W., HAINES B.M. & WALKER M.P. (1986) - Influence of proteoglycan removal on opening-up in the beamhouse. J. of Am. Leather Chem. Ass. (81)85-100.

ALEXANDER K.T.W & KEMP P.D. (1984) - The determination of hyaluronic acid and dermatan sulphate in hides and skins. BLC Information Document ID-106*.

ALEXANDER K.T.W. & STOSIC R.G. (1993) - A new non-destructive softness test. J. of Soc. Leather Tech. & Chem. 77(5)139-142.

ANON (1987) - Patchy progress in African Leather Industry. Leather, April 1987 189(4842)20-21.

BAILEY A.J. & ROBINS S.P. (1973) - Development and maturation of the crosslinks in the collagen fibres of skin. Font. Matrix Biol. (1)130-156.

BAILEY A.J. & SHIMOKOMAKI M. (1971) - Age related changes in the reducible crosslinks of collagen. FEBS Letters (16)86-88.

BANCROFT J.D. & STEVENS A. (1982) - The theory and practice of histology technique. 2nd Ed. Churchill Livingstone ISBN 0 443 02006 X.

BAPTIST R. & GALL C. F. (1992) - Global appraisal of livestock farming systems and study of their organisational levels: concepts, methodology and results. Commission of the European Community, Agrimed Research Programme. ISSN 1018-5598.

BARLOW J.R. (1976) - Preservation of partially processed hides and skins, a review: Part I. Rawstock. Trop. Sci. 18(2)63-92.

BARRETT J.C. (1985) - Artisanal tanning and leather craft in Djibouti. Leather (187)225-227.

BARRETT J.C. (1986) - Short term preservation of hides in Zimbabwe. J. Soc. of Leather Tech. & Chem. 70(3)83-89.

BELLAVER C. (1980) - As Peles. Circular Tecnica No. 3, EMBRAPA, Sobral-CE.

BENDER D.A. (1993) - An introduction to nutrition and metabolism. UCL Press. ISBN 1-85728-078-4.

BITCOVER E.H. & EVERETT A.L. (1978) - Correlation of chrome and fat content with leather strength. Technical Note. J. Am. Leather Chem. Ass. 73(3)121-125

BLMRA (1957) - Hides, skin and leather under the microscope.

BOCCONE R.L., FONTANA J. & KAMP G. (1977) - Topographic distribution of properties in softy shoe upper leathers. J. Soc. of Leather Tech. & Chem. 61(5)106-111.

BONSMA J. (1980) - Livestock production, a global approach. Tafelberg. ISBN 0-624-01393-6.

BOWES J.H. (1959) - Hydroxyproline as a measure of hide substance. J. Soc. of Leather Tech. & Chem. 43(6)203-211.

BOWES J.H., CAVE J.C. & ELLIOTT R.G.H. (1951) - Interfibrillary proteins and mucopolysaccharides as factors inhibiting the rehydration of dried hides. BLMRA Laboratory Report 30(2)172*.

BOWES J.H. & RAISTRICK A.S. (1966) - Recent developments in livestock production and their influence on hides, skins and leather. BLMRA Laboratory Report XLV(1)39-51*.

BOWES J.H., RAISTRICK A.S., DEXTER A., MILWARD F. & BURT M. (1967) - Composition and properties of sheepskins. (i) Effect of age, rate of growth and season of kill. BLMRA Laboratory Report 46(1)177-196*.

BRUNSDON R.V. & VLASSOF A. (1986) - Longer term benefits seen for post lamb drenching. New Zealand J. of Agric. (51)36-37.

BRUYN J.F.de, NAUDE R.T., SMIT M.E., POTGIETER E.J.,CLOETE A., RUSSELL A.E., GALLOWAY A.C. & VOSLOO W.A. (1987) - The influence of compensatory growth on certain hide and leather characteristics. J. Soc. of Leather Tech. & Chem. 71(6)169-186.

BS1309:(1974) method(3); based on SLC(3) (IUC/5) Determination of volatile matter.

BS1309:(1974) method(4); based on SLC(4) (IUC/4) Determination of substances (fats and other solubles) soluble in dichloromethane (CH_2Cl_2).

BS1309:(1974) method(7); based on SLC(7) (IUC/10) Determination of nitrogen and hide substance.

BS3144:(1968) Method (3); based on SLP(4) (IUC/4) Measurement of thickness.

BS3144:(1968) Method (5); based on SLP(6) (IUC/6) Measurement of tensile strength, percentage elongation caused by a specified load and percentage elongation at break.

BS3144:(1968) Method (6); based on SLP(9) (IUP/9) Measurement of distension and strength of grain by the ball burst test.

BURNS M. (1965) - The histology of some Nigerian goats. Trop. Agri. Trind. 42(3)243-259.

CATER C.W (1972) - Applications of isometric tension to the selection of pickled sheepskins. BLMRA Laboratory Report LR-9*.

CLARK J. (1986) - Influence of diet on wool and leather characteristics of ewe and wether Southdown cross Romney lambs. N.Z. Leather & Shoe Research Association. Research Report RR36.

COOK G.L., COVINGTON A.D., SPARKS T.H., SYKES R.L. & GOODMAN J. (1990) - a survey of factors affecting butcher strain in sheepskins. A collaborative study by BLC and MLC. British Leather Confederation Information Document ID-147*

COOP R.L., SYKES A.R. & ANGUS K.W. (1982) - The effect of three levels of intake of *Ostertagia circumcincta* larvae on growth rate, food intake and body composition of growing lambs. J. of Agric. Sci. (Cambridge) (98)247-255.

DEVENDRA C. & BURNS M. (1970) - Goat production in the tropics. Technical Communication, Commonwealth Bureau of Animal Breeding and Genetics No.19.

DEVENDRA C. & COOP I.E. (1982) - Ecology and distribution. Ch.1 in Sheep and Goat Production. Ed. Coop I.E., Elsevier Sci. Pub. Co. Amsterdam.

DEVENDRA C. & McLEROY (1982) - Goat and sheep production in the tropics. Intermediate Tropical Agricultural Series. Longman, London.

EPSTEIN H. (1965) - Regionalization and stratification in livestock breeding with special reference to the Mongolian People's Republic. Anim. Breed Abstr. (33)169-181.

EVERETT A.L. & HANNIGAN M.V. (1978) - Influence of animal factors and processing treatments on grain layer and total thickness of cattle hides. J. Am. Leather Chem. Ass. 73(5)207-221.

F.A.O. (1992a) - Production Year Book Vol. 45, Rome.

F.A.O. (1992b) - World statistical compendium for raw hides and skins, leather and leather footwear 1972-1990. FAO, Rome.

FIGUEIREDO E.A.P. (1990) - (EMBRAPA) Personal communication.

FIGUEIREDO E.A.P., SHELTON M. & PANT K.P. (1982) - Goat skins. Proc. 3rd. Int. Conf. on Goat Production & Disease. Jan. 10-15th 1982. Tucson, Arizona, USA. Pgs. 488-490.

GALL C. (1981) - Goat Production. Academic Press, London.

GBOLAGUNTE G.D., ISITOR G.N., OWOEYE L.D., EJILA A., SALAKO M.O. & MSHELBWALA A.S. (1987) - Comparative study of the histopathology and physical quality of chrome-tanned shoe upper leather from hides of treated and untreated dermatophilosis-infected cattle. J. Leather Research 5(2)33-40.

GBOLAGUNTE G.D. & JAMDAR M.N. (1984) - Histology of camel (*Camelus dromedarius*) hide in relation to leather manufacture. J. Leather Research 2(1)1-9.

GEORGI J.I. & GEORGI M.E. (1990) - Parasitology for veterinarians. 5th Ed. Saunders ISBN 0 7216 3058-8.

GRACEY J.F. & COLLINS D.S. (1992) - Meat Hygiene. 9th Ed. Bailliere Tindall ISBN 0702014958.

GRATACOS E., COSTA R., SANS J. & PORTAVELLA M. (1989) - Grain strain in sheepskins produced during flaying. Colomer Munmany S.A.

GREEN H.F. (1956) - A survey of skin diseases of goats in Kenya and their effect on the finished leather. J. Soc. of Leather Tech. & Chem. 40(8)259-264.

GREENWOOD P.L., FINN J.A. and MAY T.J. (1992) - A survey to assist development of carcass description and live assessment systems for goats. Animal production in Australia. Proceedings of the Australian society of animal production. Nineteenth biennial conference. Vol.19. Pg. 277.

HAAS D.E. & CHEMITEI V.I.L. (1973) - Observations on indigenous and Boer X indigenous crossbred kids. UNIDO. FAO Sheep and goat development project working paper No.5.

HAINES B.M. (1974) - Fiber structure and leather physical properties of leather. J. Am. Leather Chem. Ass. 69(3)96-111.

HAINES B.M. (1978) - Leather defects originating at the farm and at the abattoir. J. Soc. of Leather Tech. & Chem. 62(2)25-47.

HAINES B.M. (1981) - Breed differences in cattle hides. J. Soc. of Leather Tech.& Chem. 65(4)70-78.

HAINES B.M. (1981) - Breed differences in hides and skins: Marketing hides and skins today and tomorrow. MLC/BLMRA publication. March 1981.

HAINES B.M. (1984) - Quality rawstock. J. Am. Leather Chem. Ass. 79(8)319-350.

HAINES B.M. (1985) - Pig skin chemical composition and structure. British Leather Confederation Laboratory Report LR-151*.

HAINES B.M & SHIRLEY S.G. (1979) - Relaxation of isometric tension: A technique for studying the maturity of sheepskin. BLMRA Information Document ID-63*.

HAINES B.M & SHIRLEY S.G. (1988) - Relaxation of isometric tension: a technique for studying the maturity of sheepskin. J. Soc. of Leather Tech. & Chem. (72)165-169.

HALLIGAN G. & JOHNSTONE A.C. (1992) - Histology of cockle lesions on New Zealand lamb skins. J. Am. Leather Chem. Ass. 87(2)39-51.

HANACZIWSKYJ P., HORIE C.V. & SHUTTLEWORTH C.A. (1989) - Hydrothermal isometric tension apparatus and its application to the study of thermal stability of preserved red deer skin. J. Soc. of Leather Tech. & Chem. 73(4)105-109.

HARKNESS R.D. (1971) - Mechanical properties of skin in relation to its biological function and its chemical components. Ch.11 in Biophysical properties of the skin. A treatise of skin, Vol.1. Ed. Elden H.R.. John Wiley & Sons, Inc. ISBN 0-471-23540-7.

HAY E.D. (1981) - Extra cellular matrix. J. Cell Biology (91)205s-223s.

HOLE L.G., TUCK-MARTIN B.S. & HALE J. (1979) - The influence of grain structure on grain crack properties of leathers. J. Soc. of Leather Tech. & Chem. 631(6)98-99.

HOLST P.J. (1986) - The world production and utilisation of goat skins. Agric. Res. St. Cowra. NSW. Australia.

HOLST P.J., ALLAN C.J., PERVEZ M. & ASH A.J. (1987) - Properties of leather produced from a sample of Australian feral goat. J. Soc. of Leather Tech. & Chem. 71(4)134-137.

HOLST P.J., ALLAN C.J., PERVEZ M. & ASH A.J. (1989) - Goat live weight and its effect on skin area, primary follicle density and leather grain appearance. J. Soc. of Leather Tech. & Chem. 73(1)13-16.

HOPKINS W.J, BAILEY D.G. WEAVER E.A & KORN A.H. (1973) - Potential short-term techniques for the preservation of cattle hides. J. Am. Leather Chem. Ass. 68(10)426-433.

HUSSAIN M.Z., NAIDU R., TUVUKI I. & SINGH R. (1983) - Goat production and development in Fiji. World Animal Rev. (48)25-32.

IBRAHIM K.E.E. & ABU-SAMRA M.T. (1987) - Studies on the defects and the economical losses on crust leather resulting from physical damage. J. Soc. of Leather Tech. & Chem. 71(2)68-74.

JARRETT A. (1977) - The physiological and pathology of the skin. Vol.3. Academic Press, London.

JENKINSON D.M. & NAY T. (1973) - quoted Gbolagunte & Jamdar (1984).

JOSEPH K.T., BOSE S.M. & NAYUDAMMA Y. (1960) - Comparative biochemistry of hides and skins collected from different regions. (1). Distribution of certain amino acids, carbohydrate constituents and lipids of skins of Uttar Pradesh and Hyderabad. Bull. Cent. Leather Res. Inst. Madras. (6)465-477.

JOSSERAND A.P. & ARIZA-NINO E.J. (1982) - The marketing of small ruminants in West Africa. Proc. 3rd. Int. Conf. on Goat Production & Disease. Jan. 10-15th 1982. Tucson, Arizona, USA. Pgs. 55-62.

KIRTON A.H. (1970) - Body and carcass composition and meat quality of the New Zealand feral goat. N.Z. J. Agric. Research 13(1)167-81.

KOPP J. & BONNET M. (1987) - Ch.9 in Advances in meat research. Vol.4. Collagen as food. Ed. Pearson A.m., Duston T.R. & Bailey A.J. Van Nostrand Reihold Co. New York.

LE LOUS M., COHEN-SOLAL L., ALLAIN J., BONAVENTURE J. & MAROTEAUX P. (1985) - Age related evolution of stable collagen reticulation in human skin. Connect. Tissue Res. 13(2)145-55.

LOEWI G. & MEYER K. (1958) - The acid mucopolysaccharides of embryonic skin. Biochem. Biophys. Acta (27)453-456.

LOUCA A., ECONOMIDOS S. and HANCOCK J. (1977) - Effects of castration on growth rates, feed conversion efficiency and carcass quality in damascus goats. Aim. Prod. (24) 387-391.

MASON I.L. (1981) - Breeds. Chp.3 in Gall (1981).

MARKS R. (1983) - Techniques for measuring mechanical properties of skin. J. Soc. Cosmet. Chem. 34(8)429-437.

MARTIN M. (1982) - Case studies of traditional marketing systems: Goats and goat products in Northeast Iran. Proc. 3rd. Int. Conf. on Goat Production & Disease. Jan. 10-15th 1982. Tucson, Arizona, USA. Pgs. 45-49.

McANULTY R.W., CLARK V.R. & CLARK A.R. (1982) - The effect of use of clean pasture and anthelmintic frequency on growth rate of hoggets. Proc. of New Zealand Soc. of Animal Production (42)187-188.

McGREGOR B.A. (1992) - Body composition, body condition scores and carcass and organ components of grazing Angora goats. In Animal production in Australia. Proceedings of the Australian society of animal production. 19th Biennial Conference. Vol.19. Pgs. 273-276.

MILLER A.T. & KARMAS E. (1985) - Age-related changes in collagen of bovine corium: relationship to histological and ultrastructure observations. J. Am. Leather Chem. Ass. 80(4)106-117.

MILNES R.H. & PETERS G.P. (1977) - The quality of some New Zealand deerskins. New Zealand Agric. Sci. 11(4)199-201.

MÖNNIG H.O. (1950) - Veterinary helminthology and entomology. 3rd Ed. Bailliere Tindall & Cox.

MOWLEM A. (1988) - Goat farming. Farming Press. ISBN 0-85236-183-1.

MUTHIAH P.L., THAMBIAH A.S., RAMANATHAN N. & NAYUDAMMA Y. (1977) - Ultrastructural observation of skin samples obtained from various parts of animal and human body. J. Soc. of Leather Tech. & Chem. 61(1)11-16.

NEUMANN R.E. & LOGAN M.A. (1950) - The determination of hydroxyproline. J. Biol. Chem (184)299-306.

OLIVANNAN M.S., RAO M.S., SUDUUA S., RAO J.B., ARUMUGHAM M.P. &

RATHNASABAPATHY V. (1977) - Studies on the leather making properties of sheepskins of Mecheri and Mandya breeds. Leather Sci. 24(11)371-377.

OKELLO K.L. & OBWOLO M.J. (1985) - Uganda: Review of the potentialities of goat production. World Animal Rev. (53)27-32.

OWEN J.E., NORMAN G.A., FISHER I.L. & FROST R.A. (1977) - Studies on the meat production characteristics of Botswana goats and sheep. 2. General body composition, carcase measurements and joint composition. Meat Sci. Vol.1. Pgs. 283-306.

PASSMAN A. (1981) - Sheep: Breed influences on pelt. N.Z. Leather & Shoe Research Association. Report of 32nd Annual Conf. of Fellmongers and Hide Processors. Pgs. 7-28.

PASSMAN A. & CLARK J. (1982) - Age influence on New Zealand sheep breeds. N.Z. Leather & Shoe Research Association. Report of 33rd Annual Conf. of Fellmongers and Hide Processors. Pgs. 41-51

PETERS D.E. & STEPHENS L.J. (1989) - The physical properties of leather from kangaroo skins. Part I. Comparison between species and sexes. J. Am. Leather Chem. Ass. 84(5)133-142.

POLLAARD J.H. (1979) - A handbook of numerical and statistical techniques. Cambridge University Press. ISBN 0-521-29750-8.

RAE A.L. (1982) - Breeding. Ch.2 in Sheep and Goat Production. Ed. Coop I.E., Elsevier Sci. Pub. Co. Amsterdam.

RAO J.S, RAO V.H., DHAR S.C. & BOSE S.M. (1985) - Effect of protein malnutrition on collagenase and certain lysosomal hydrolases in relation to lysosomal stability. Leather Sci. 32(9)224.

RAUN N.S. (1982) - The emerging role of goats in world food production. Proc. 3rd. Int. Conf. on Goat Production & Disease. Jan. 10-15th 1982. Tucson, Arizona, USA. Pgs. 133-41.

REED R. (1953) - Significance of mucoids of hides and skins in the limeyard. J. Soc. of Leather Tech. & Chem. (37)5-81.

RUSSELL A.E. (1988) - Stress-strain relationships in leather and the role of fibre structure. J. Soc. of Leather Tech. & Chem. 72(4)121-134.

RUSSELL A.E., GALLOWAY A.C., BOCCARD R.L. & NAUDE R.T. (1977) - Hide and leather characteristics of Afrikaner and Friesland bulls and steers slaughtered at various ages between birth and 24 months. J. Soc. of Leather Tech. & Chem. 61(1)1-10.

RUSSELL A.E., GALLOWAY A.C., NAUDE R.T., ARGO A. & VENTER H.J. (1980) - Hide and leather characteristics of young Afrikaner-type steers slaughtered at four different live masses. J. Soc. of Leather Tech. & Chem. 64(1)9-15.

RUSSELL A., PINCHUCK S., BRUYN J.E. de & NAUDE R.T. (1988) - The influence of compensatory growth on certain hide and leather characteristics. Part II. Hide and leather yield and leather physical characteristics. J. Soc. of Leather Tech. & Chem. 72(6)193-209.

SCHRÖER T. (1986) - Survey of goat skin quality in N. Tunisia and investigations of skin preservation methods with special reference to appropriate technologies. Ph.D. Dissertation. Justus-Liebig University, Giessen. IHATIS summary Dec.1986.

SLC(8):1966 (IUC/8) Determination of chromic oxide (Cr_2O_3).

SLC(21):1966 (IUC/7) The determination of hydroxyproline in materials containing collagen.

SPIKER S.A., CUMMINS L.A. and BRIEN F.D. (1992) - Manipulation of sex to modify growth and carcass composition of prime lambs. Animal production in Australia. Proceedings of the Australian society of animal production. Nineteenth biennial conference. Vol.19. Pgs. 163-166.

STEPHENS L.J. & PETERS D.E. (1989) - The physical properties of leather from kangaroo skins. Part II. Variation in properties with sampling position. J. Am. Leather Chem. Ass. 84(5)143-149.

STOSIC R.G. (1992) - BLC Prototype Softness Gauge. BLC Laboratory Report LR-193*.

SYKES A.R., McFARLANE R.G., & HAMILTON A.S. (1992) - Parasites, immunity and anthelmintic resistance. Ch.8 in Progress in sheep and goat research. Ed. Speedy.

SYMONS L.E.A (1985) - Anorexia: Occurrence, pathophysiology and possible causes in parasitic infections. Advances in parasitology (24)103-133.

TANCOUS J.J & SCHMITT R. (1967) - Pulpiness and weakness in side upper leather as related to fresh hides. J. Am. Leather Chem. Ass. 62(12)781-804.

TRINICK J.E. & SHIRLEY S.G (1972) Modifications to BLMRA isometric tension test apparatus and method. BLMRA Information Document ID-52*.

TUDOR G.D. (1992) - Effect of diet on fat deposition in cattle. Animal production in Australia. Proceedings of the Australian society of animal production. Nineteenth biennial conference. Vol.19. Pg. 89.

UNIDO (1987) - Report from the regional meeting on the leather and leather products industry in africa. Alexandria, Egypt 12-15 Jan. (IPCT.14).

UPTON M. (1985) - Returns from small ruminant production in S.W.Nigeria. Agric. Systems 17(2)65-83.

URBANIAK M.A. (1973) - The influence of some enzyme preparations on components of skin. J. Soc. of Leather Tech. & Chem. 57(2)39-43.

URQUHART G.M., ARMOUR J., DUNCAN J.L., DUNN A.M. & JENNINGS F.W. (1992) - Veterinary Parasitology. Longmans Scientific & Technical Press, London. ISBN 0582 40906-3.

VENKATESTAN R.A. (1977) - Survey of incidence of various surface defects in goat and sheepskins in Madras. Leather Sci. 24(8)255-265.

VOS A. & VLIMMEREN P.J. van (1973) - Topographic differences in physical properties. J.Soc. of Leather Tech. & Chem. 57(4)93-98.

WALKER C.A. (1957) - The skin thickness of cattle in Northern Rhodesia. J. Agric. Sci. 49(211-13).

WANG Y. (1992) - Characteristic of Brazilian goat and sheep skin and leather. M.Phil thesis, University of Leicester.

WILSON P.N. (1958) - The effects of plane of nutrition an the growth and development of the east African dwarf goat. Part 1 Effects of plane of nutrition on the weight gains and the external measurements of kids. J. Agric. Sci. (Cambridge) (50)198-210.

WILSON R.T. (1982) - The economic and social importance of goats and their products in the semi-arid arc of Northern Tropical Africa. Proc. 3rd. Int. Conf. on Goat Production & Disease. Jan. 10-15th 1982. Tucson, Arizona, USA. Pgs. 186-91.

WILSON R.T., ABDARAHAMANE D. & WAGENAAR K. (1985) - Mixed herding and the demographic parameters of domestic animals in arid and semi-arid zones of tropical Africa. In Population, health and nutrition in Sahel. Ed. Hill A.G., KPI Routledge, Kegan Paul.

* - Restricted circulation.

SLP - Society of Leather Technologists and Chemists Physical Testing Methods.

IUP - International Union of Leather Chemists Societies Physical Testing Methods.

209