

Aus dem Institut für Nutztierwissenschaften der Humboldt-Universität zu Berlin

DISSERTATION

**Pre-weaning growth performance of hair x
mutton sheep crosses and post-weaning
growth and physiological reaction in
response to different feeding levels and high
ambient temperature**

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Zusammenfassung

Ziel der Arbeit war es, die Leistung von Kamerunlämmern und K1- und K2-Kreuzungslämmern vor und nach dem Absetzen bei unterschiedlichen Haltungsbedingungen zu untersuchen. Bei Wachstumsversuchen nach dem Absetzen ging es darum die Effekten verschiedener Fütterungsniveaus bei Stalltemperatur zu untersuchen und die Reaktion von Kamerunlämmern und K1- und K2-Kreuzungslämmern festzustellen und zu vergleichen. In einem weiteren Versuch in der Klimakammer (bei 31°C/50% relativer Luftfeuchte am Tage und 15°C/70% relativer Luftfeuchte nachts) wurde das Wachstum von Kamerun- und K2-Kreuzungslämmern und dessen physiologischen Reaktionsmuster untersucht. Die Milchleistung von Kamerun- und K1-Mutter-Tiere wurde ermittelt und verglichen unter Anwendung der "Suckling"-Methode.

Die Kreuzungslämmer wurden durch Kreuzungen von Kamerunhaarschafen mit Deutschen Rassen (d. h. Texel, Blauköpfiges Fleischschaf, Rauhwolliges Pommersches Landschaf, Coburger Fuchsschaf, Braunes Bergschaf, Merino Landschaf, Weißes Ostfriesisches Milchschaaf und Braunes Ostfriesisches Milchschaaf) erzeugt. Zur Ermittlung des Wachstums vor dem Absetzen standen folgende Versuchstiere zur Verfügung: 67 (9 Kamerun, 31 K1 und 27 K2) männliche und weibliche Lämmer in der laktogenen Phase im Jahr 1994 und 60 (11 Kamerun, 21 K1 und 28 K2) männliche und weibliche Lämmer in der laktogenen Phase im Jahr 1995. Zur Ermittlung des Wachstums nach dem Absetzen standen folgende Versuchstiere zur Verfügung: 30 (10 Kamerun, 10 K1 und 10 K2) abgesetzte männliche und weibliche Lämmer im Jahr 1995 und 10 (5 Kamerun und 5 K2) abgesetzte männliche und weibliche Lämmer für die Temperaturbehandlung in der Klimakammer im Jahr 1996. Für den Milchleistungsversuch standen folgende Versuchstiere zur Verfügung: 17 (8 Kamerun und 9 K1) laktierende Mutterschafe im Jahr 1995.

Zahlenmäßig wurden ca. 46% der K1-Lämmer durch Kreuzung zwischen Kamerun x Texel; und ca. 47% der K2-Lämmer durch Kreuzung zwischen K1 (Kamerun x Weißes Ostfriesisches Milchschaaf) und K1 (Kamerun x Braunes Ostfriesisches Milchschaaf) erzeugt.

Die folgenden Parameter wurden benutzt: Körpergewicht, Milchleistung, Futteraufnahme, Wasseraufnahme, Rektaltemperatur, Atemzüge pro Minute und Schlachtkörperwert.

Alle Experimente wurden in der Tierversuchstation Dahlem der Landwirtschaftlich-Gärtnerische Fakultät der Humboldt-Universität zu Berlin durchgeführt.

Die Ergebnisse der Untersuchungen sind wie folgt zusammengefaßt:

1. Vergleich des Wachstums von Lämmern unterschiedlicher Genotypen während der laktogenen Phase

- Das Geburtsgewicht ($p \leq 0.001$) und die ermittelte tägliche Zunahme nach der Geburt bis zum Alter von 90 Tagen ($p \leq 0.001$) waren bei den K1- und K2-Kreuzungslämmern signifikant höher als bei den Kamerunlämmern.
- Das Geburtsgewicht von K1-Kreuzungslämmern war signifikant ($p \leq 0.001$) höher als bei den K2-Kreuzungslämmern. Im Gegensatz dazu war die ermittelte tägliche Zunahme nach der Geburt bis zum Alter von 90 Tagen signifikant ($p \leq 0.05$) höher bei den K2- als bei den K1-Kreuzungslämmern.
- Die ermittelte tägliche Zunahme über den Zeitraum von 0 bis 30 Tagen, 30 bis 60 und 60 bis 90 Tagen nach der Geburt war bei den Kamerunern konstant. Bei den K1- und K2-Kreuzungslämmern nahmen sie während des Versuchsverlaufes ab.

2. Milchleistung der Mutterschafe ermittelt über die "Suckling"- Methode

- Die Milchleistung von K1-Mutterschafen war signifikant ($p \leq 0.001$) höher als die der Kamerun-Mutterschafe.
- Die Milchleistungsverlauf der K1-Mutterschafe zeigte nach dem Maximum in der ersten Laktationsphase einen allmählichen Abfall. Im Gegensatz dazu fiel die Milchleistung der Kamerun-Mutterschafe nach der dritten Laktationswoche stark ab.

3. Vergleichendes Wachstum der Lämmer unterschiedlicher Genotypen nach dem Absetzen

3.1. Einfluss verschiedener Fütterungsniveaus

Im Vergleich zwischen alternierender Hoch-Niedrig- und Niedrig-Hoch-Fütterung ergab sich, daß bei letzteren Fütterungsregime ein signifikant ($p \leq 0.05$) höheres Lebendgewicht in der zwölften Woche ermittelt wurde. Das Endgewicht der K1- und K2-Kreuzungslämmer war signifikant ($p \leq 0.001$) höher als das der Kameruner. Der Unterschied zwischen den K1- und K2-Kreuzungslämmern war nicht signifikant, aber die K2-Tiere haben ein größeres Endgewicht erlangt als die K1-.

Die tägliche Zunahme war als Folge der Niedrig-Hoch-Fütterung signifikant ($p \leq 0.001$) höher als der umgekehrten Fütterungsform. K1- und K2-Kreuzungslämmer haben eine signifikant ($p \leq 0.001$) höhere tägliche Zunahme erlangt als die Kamerunlämmer. In der Tendenz erreichten die K1-Kreuzungslämmer eine höhere tägliche Zunahme als die K2-. Dieser Unterschied konnte statistisch, jedoch nur in der 2. Versuchsabshnitt gesichert werden. Der Verlauf von ermittelter täglicher Zunahme pro Woche zeigt ein unterschiedliches Bild zwischen den beiden Fütterungsregimen.

Die Aufnahme von der gesamten umsetzbaren Energie war zwischen den Fütterungsregimen (Hoch-Niedrig- und Niedrig-Hoch-Fütterung) nicht unterschiedlich. Dagegen zeigte die Energieaufnahme oberhalb des Erhaltungsbedarfes signifikante ($p \leq 0.001$) Unterschiede, indem in der Niedrig-Hoch-Fütterungsregime in der 2. Versuchshälfte mehr Energie aufgenommen wurde. Zwischen den verschiedenen Genotypen gab es keine signifikante Unterschiede, jedoch nahmen in der Tendenz die Kameruner die höchste Energiemenge oberhalb des Erhaltungsbedarfes auf und die K1-Tiere die niedrigste.

Die Weizenstrohaufnahme war über den gesamten Versuchszeitraum betrachtet nicht unterschiedlich zwischen den Fütterungsregimen. Während der Niedrig-Fütterungsphasen wurde jeweils signifikant ($p \leq 0.05$) mehr Weizenstroh aufgenommen als in den Hoch-Fütterungsphasen. Die Weizenstrohaufnahme war zwischen den K1- und K2-Kreuzungslämmern im Vergleich zu den Kamerunlämmern aufgrund von der höheren Lebendmasse signifikant ($p \leq 0.001$) erhöht. Bei hohem Fütterungsniveau war die relative Aufnahme von Weizenstroh (Trockensubstanz von Weizenstroh: Gesamt-Trockensubstanz) bei den K1- und K2-Tieren höher als bei den Kamerunern.

3.2. Einfluss erhöhter Lufttemperatur während des Tages und alternierender Fütterungsniveaus

Die K2-Kreuzungslämmer haben über die Zeit des Versuchs in der Klimakammer höhere tägliche Zunahmen erlangt als die Kamerunlämmer, aber der Unterschied zwischen ihnen war nicht signifikant. Die K2-Kreuzungslämmer haben erst während der zweiten Hoch-Fütterungs-Phase von Woche 9 bis Woche 12 signifikant ($p \leq 0.05$) höhere tägliche Zunahmen erlangt als die Kamerunlämmer. Die männlichen Tiere erreichten während der letztgenannten Phase und während der Zeit des ganzen Versuchs signifikant ($p \leq 0.05$) höhere tägliche Zunahme als die weiblichen Tiere.

Die Aufnahme von Energie ($p \leq 0.01$) und Krafffutter ($p \leq 0.05$) war bei den K2- Kreuzungslämmern signifikant höher als bei den Kamerunlämmern und bei den männlichen Tieren signifikant höher als bei den weiblichen während der Zeit des ganzen Versuchs. Nichtsdestoweniger war die Aufnahme von Energie oberhalb des Erhaltungsbedarfes signifikant ($p \leq 0.01$) höher bei den Kamerunlämmern als bei den K2- Kreuzungslämmern während der ersten Hoch-Fütterungs-Phase von Woche 1 bis Woche 4 und während der Zeit des ganzen Versuchs ($p \leq 0.05$). Die Aufnahme von Energie oberhalb des Erhaltungsbedarfes war bei den männlichen Tieren auch signifikant ($p \leq 0.05$) höher als bei den weiblichen während der zweiten Hoch-Fütterungs-Phase von Woche 9 bis Woche 12.

Die Aufnahme von Weizenstroh war signifikant ($p \leq 0.05$) höher bei den K2- Kreuzungslämmern als bei den Kamerunlämmern während der ersten Hoch-Fütterungs-Phase von Woche 1 bis Woche 4.

Die erhöhte Tagestemperatur und die Hoch-Niedrig-Hoch-Fütterung ergaben kein physiologisches Hindernis zur Haltung von Kamerun- und K2- Kreuzungslämmern.

Mit Ausnahme von den K2- Kreuzungslämmern während der restriktiven Phase in der 5. - 8. Woche, war die Rektaltemperatur gemessen um 12⁰⁰ Uhr bei 31⁰C/50% relative Luftfeuchte immer niedriger als Rektaltemperatur gemessen um 20⁰⁰ Uhr bei 15⁰C/70% relative Luftfeuchte, ungeachtet des Genotyps. Die weiblichen Tiere haben immer höhere Rektaltemperatur- und Atemfrequenzwerte erlangt als die männlichen. Niedrige Rektaltemperatur bei den männlichen Tieren war mit höherer Energieaufnahme verbunden (siehe oben). Atemfrequenz war bei den K2- Kreuzungslämmern meist

höher als bei den Kamerunlämmern. Nach der 2. und der 3. Versuchsphase war der Unterschied der Rektalttemperatur gemessen um 12⁰⁰ Uhr bei 31⁰C/50% relativer Luftfeuchte zwischen den Kamerunern und den K2- Kreuzungslämmern und zwischen den männlichen und den weiblichen Tieren erhöht. Während der Niedrig-Fütterung-Phase von Woche 5 bis Woche 8 ergaben sich auch erhöhte Unterschiede in der nächtlichen Rektalttemperatur gemessen um 20⁰⁰ Uhr bei 15⁰C/70% relativer Luftfeuchte zwischen den Kamerunern und den K2- Kreuzungslämmern und auch zwischen den männlichen und weiblichen Tieren.

Die Unterschiede der Rektaltemperaturen gemessen um 12⁰⁰ Uhr bei 31⁰C/50% relativer Luftfeuchte und um 20⁰⁰ Uhr bei 15⁰C/70% relativer Luftfeuchte kompensierten sich zwischen den Kamerunlämmern und den K2- Kreuzungslämmern: tagsüber waren die Temperatur-Werte bei den Kamerunlämmern erniedrigt, nachts erhöht gegenüber den K2- Kreuzungslämmern. Eine derartige Kompensation der Rektalttemperatur gemessen um 12⁰⁰ Uhr bei 31⁰C/50% relativer Luftfeuchte und um 20⁰⁰ Uhr bei 15⁰C/70% relativer Luftfeuchte zwischen männlichen und weiblichen Tieren, trat nicht auf.

Als Folge der Niedrig-Fütterung-Phase von Woche 5 bis Woche 8 war der Unterschied in der Atemfrequenz gemessen um 12⁰⁰ Uhr erhöht bei den Kamerunlämmern gegenüber den K2- Kreuzungslämmern. Während der Niedrig-Fütterung-Phase von Woche 5 bis Woche 8 und während der zweiten Hoch-Fütterung-Phase von Woche 9 bis Woche 12, war der Unterschied der Atemfrequenz bei den männlichen gegenüber den weiblichen Tieren auch erhöht.

4. Schlachtwert

4.1. Einfluss verschiedener Fütterungsniveaus

Die signifikante Erhöhung der täglichen Zunahme als Folge von Niedrig-Hoch-Fütterung ist das Ergebnis der Erhöhung der Gewichte der Verdauungsorgane. Niedrig-Hoch- Fütterung führte zu einer Erhöhung der Gewichte von Leerkörper, Muskel, Fett (außer von Kammfett) und Knochen (außer der Knochengewichte von Schulter, Kamm und Hals) der selektierten 7 wertvollen Körperteile, die aber nicht statistisch gesichert werden konnte.

Das Leerkörpergewicht war bei den K2-Kreuzungslämmern größer als bei den K1-. Auch das relative Gewicht (Muskel: Körperteil) der meisten wertvollen Körperteile (Schulter, Rücken und Keule) war bei den K1- und K2-Tieren signifikant höher als bei den Kamerunern. Für die Körperteile, Brust und Hals, haben die K2-Tiere einen höheren Wert erlangt als die Kamerun- und K1-Tiere.

Das Fellgewicht war bei den K1- und K2-Kreuzungslämmern signifikant ($p \leq 0.001$) höher als bei den Kamerunlämmern. Der Unterschied zwischen den K1- und K2-Kreuzungslämmern war nicht signifikant, aber die letztgenannten haben einen höheren Wert erlangt.

Der Effekt der Fütterungsformen auf relatives Gesamtfett, Nieren-Fett und Magen-Darm-Fett war nicht signifikant. Der Effekt von Genotyp ($p \leq 0.05$) und Geschlecht ($p \leq 0.05$) auf relatives Gesamtfett, Nieren-Fett und Magen-Darm-Fett war aber signifikant. Die Kamerunlämmer haben signifikant höhere Werte erlangt als die K1- und K2-Kreuzungslämmer. Der Unterschied zwischen den K1- und K2-Kreuzungslämmern war nicht signifikant, aber letztgenannten haben einen höheren Wert erlangt.

4.2. Einfluss höher Lufttemperatur während des Tages und alternierender Fütterungsniveaus

Die K2-Kreuzungslämmer erzielten ein größeres Schlachtkörpergewicht bei fast allen Merkmalen gegenüber den Kamerunlämmern. Relatives Gewicht (Muskel: Körperteil) von Keule und Dünung war bei den K2 hochsignifikant ($p \leq 0.001$) höher als bei den Kamerunern. Im Vergleich zum letztgenannten Experiment, scheint der Fleischeinsatz der K2-Tiere gegenüber den Kamerun- für den meisten wertvollen Körperteilen (außer von Keule und Hals) benachteiligt zu sein als Folge von höher Temperatur.

In der Klimakammer unter obengenannten Fütterungsregime und mit alternierender höher und niedriger Temperatur tagsüber bzw. nachts erzielten die Kamerunlämmer ein signifikant höheres relatives Gewicht bezüglich Gesamtfett ($p \leq 0.01$), Nieren-Fett ($p \leq 0.001$) und Magen-Darm-Fett ($p \leq 0.001$) gegenüber den K2-Kreuzungslämmern. Im Vergleich zu Hoch-Niedrig- und Niedrig-Hoch-Fütterung im Jahr 1995 unter Stalltemperaturbedingungen war in der Klimakammer (1996) eine geschlechtsbedingte Umsteuerung der Ablagerung vom relativen Gewicht von Magen-Darm-Fett festzustellen: die männlichen Tiere erzielten höheren Werte gegenüber den weiblichen, der

Unterschied zwischen ihnen war nicht signifikant, auch wenn dies absolute signifikant ($p \leq 0.05$) war. Die Rektaltemperatur- und Atemfrequenzwerte während des Tages waren bei den Kamerunlämmer und den männlichen Tieren signifikant niedriger als bei den K2- Kreuzungslämmern bzw. den weiblichen Tieren. Die Umsteuerung von der Ablagerung von innerem Fett unter hohen Temperaturbedingungen könnte einen Thermoregulationsmechanismus mit Langzeitwirkung darstellen.

Kurzfassung

Die Erhöhung der tierischen Leistung von Nutztieren in den Tropen kann am schnellsten durch Kreuzungszucht realisiert werden.

Ziel der vorliegenden Arbeit war es, die Leistung von Kamerun-Schafen (C) und Ihren Kreuzungen (Kamerun x Fleischschaf, F1) und (F2 aus Kamerun x Milchschaaf) unter verschiedenen Fütterungs- und Haltungsbedingungen zu vergleichen.

Folgende Merkmale wurden analysiert:

- Wachstum vor dem Absetzen über 90 Tage; 127 Tiere; C, F1 und F2,
- Wachstum nach dem Absetzen unter verschiedenen Fütterungsbedingungen; Wechsel vom 1,5-fachen des Erhaltungsbedarfs zu ad libitum Fütterung und umgekehrt; 6 Wochen Dauer; 30 Tiere; C, F1 und F2,
- Haltung der Lämmer unter zeitlich begrenztem Temperaturstress (8 Stunden täglich bei 31°C und 50% rel. Luftfeuchte); Dauer 12 Wochen; 10 Tiere C und F,
- Analyse von Schlachtkörpern nach Versuchsende jeden Versuches; 40 Lämmer, C, F1 und F2.

Ergebnisse:

- Während der ersten Aufzugphase zeigten die Kreuzungstiere mit 213g/Tag (F1) und 236 g/Tag (F2) eine um 50 bzw. 65% erhöhte Lebendmassezunahme gegenüber den Kamerun-Lämmern (143g/Tag). Die Differenz zwischen F1 und F2 resultierte aus der unterschiedlichen Milchleistung der Muttertiere.
- Der zeitlich begrenzte Hitzestress führte zu keinen unterschiedlichen physiologischen Reaktionen zwischen den Rassen.
- Es gab keine signifikanten Unterschiede hinsichtlich der relativen Körperzusammensetzung zwischen den Rassen. Die Kreuzungstiere hatten eine signifikant erhöhte Masse des Verdauungstraktes.

Schlußfolgerungen:

Kreuzungszucht zwischen indigenen und exotischen Rassen ist in den Tropen eine geeignete Methode die Fleischerzeugung zu erhöhen, allerdings nur, wenn die Futtermittelversorgung gesichert ist. Hitzestress über eine begrenzte Zeit am Tag ist für die getesteten Rassen ohne Leistungseinbußen verträglich.

Abstract

Crossbreeding between indigenous and exotic sheep breeds is the fastest method of increasing the performance of sheep in the tropics.

The aim of this work was to assess the performance of Cameroon sheep (C) and their crossbreds (Cameroon x Mutton, F1) and (F2 from Cameroon x Milk sheep) under different housing and feeding conditions.

The following traits were analysed:

- Pre-weaning performance during the first 90 days; 127 animals, C, F1 and F2.
- Post-weaning growth performance at different feeding levels; changing from 1.5 x maintenance to ad libitum feed intake and vice versa; duration 6 weeks; 30 animals; C, F1 and F2.
- Housing of lambs under temporal heat stress (8 hours daily at 31°C and 50% relative humidity); duration 12 weeks; 10 animals, C and F2
- Carcass traits; 40 lambs, C, F1 and F2.

Results:

- During the pre-weaning period the crossbred lambs showed a higher live weight gain than the Cameroon lambs, 213g/d (F1); 236g/d (F2) and 143g/d (C) respectively, that is an increase of 50% and 65% resp. The differences between the F1 and F2 resulted from the different milk yields of the ewes.
- The heat stress over 8 hours did not lead to different physiological reactions between the breeds.
- There were no significant differences in the relative carcass traits between the breeds. The GIT-weight was increased significantly in the crossbreds.

Conclusion:

Crossbreeding of indigenous and exotic sheep breeds is a suitable method for increasing meat production in the tropics if the feed supply is guaranteed. Heat stress over a limited time is not crucial for the performance of all breeds.

Schlagwörter:

Schafe, Kreuzung, Wachstumsleistung, Hitzestress, Fleischqualität

Keywords:

sheep, crossbreeding, growth performance, heat stress, carcass traits

Contents

1	Introduction	12
1.1	Statement of the problem	12
2	Review of literature	14
2.1	Production performance of sheep with relevance to the tropics	14
2.1.1	Performance of mutton sheep breeds and their crosses under tropical conditions	14
2.1.1.1	Growth performance	14
2.1.1.2	Importance of vlies	17
2.1.1.3	Milk yield performance	17
2.1.2	Effect of restricted feeding and realimentation on growth	18
2.1.2.1	Effect of restricted feeding	18
2.1.2.2	Effect of realimentation on growth	19
2.1.3	Physiological reaction to high ambient temperature	22
2.1.3.1	Effect on body temperature	22
2.1.3.2	Effect on breathing rate	24
2.1.3.3	Effect on feed intake and digestibility	25
2.1.3.4	Effect on production	26
3	Main findings from survey of literature and objective	28
4	Materials and Methods	30
4.1	Comparative pre-weaning growth performance of lambs of different genotypes	31
4.1.1	Animals used	31
4.1.2	Feeding	31
4.1.3	Housing of animals	31
4.1.4	Management of experimental animals	31
4.2	Milk yield performance of Cameroon and C1 ewes rearing lambs using the suckling method	31
4.2.1	Animals used	31
4.2.2	Feeding	32
4.2.3	Housing of animals	32
4.2.4	Management of experimental animals	32
4.3	Comparative post-weaning growth performance of lambs of different genotypes	32
4.3.1	Influence of different feeding levels	32
4.3.1.1	Animals used	32
4.3.1.2	Feeding	33
4.3.1.3	Housing of animals	33
4.3.1.4	Management of experimental animals	33

4.3.2	Reaction to high ambient temperature during the day and of alternating feeding levels	33
4.3.2.1	Animals used	34
4.3.2.2	Feeding	34
4.3.2.3	Housing of animals	34
4.3.2.4	Management of experimental animals	34
4.4	Carcass evaluation	35
4.5	Analysis of data	36
4.6	Basic models of the experiments	36
5	Results	39
5.1	Pre-weaning growth performance of lambs	39
5.2	Milk yield performance of Cameroon and C1 ewes using the suckling method	40
5.3	Comparative post-weaning growth performance of lambs of different genotypes	42
5.3.1	Influence of different feeding levels on performance	42
5.3.2	Reaction to high ambient temperature during the day and of alternating feeding levels	52
5.3.2.1	Post-weaning growth performance	52
5.3.2.2	Physiological reaction to high ambient temperature	59
5.4	Carcass evaluation	64
5.4.1	Influence of different feeding levels on performance	64
5.4.2	Reaction to high ambient temperature during the day and of alternating feeding levels	71
5.4.3	Distribution of internal fat in response to different levels of feeding under stall temperature conditions (1995) and high ambient temperature during the day with alternating feeding levels (1996)	78
6	Discussion	82
6.1	Comparative pre-weaning growth performance of lambs of different genotypes	82
6.2	Milk yield performance of Cameroon and C1 ewes using the suckling method	82
6.3	Comparative post-weaning growth performance of lambs of different genotypes	83
6.3.1	Influence of different feeding levels on performance	83
6.3.2	Reaction to high ambient temperature during the day and of alternating feeding levels	86
6.4	Pattern of deposition of kidney and mesenteric fat of slaughtered lambs following exposure to different feeding levels under stall ambient temperature conditions (1995) and to high ambient temperature during the day with alternating feeding levels (1996)	89
6.5	Limitations related to experimental conditions	90

7	Summary	91
7.1	Comparative pre-weaning growth performance of lambs of different genotypes	91
7.2	Milk yield performance of Cameroon and C1 ewes using the suckling method	91
7.3	Comparative post-weaning growth performance of lambs of different genotypes	92
7.3.1	Influence of different feeding levels on performance	92
7.3.2	Reaction to high ambient temperature during the day and of alternating feeding levels	92
7.4	Carcass evaluation	93
7.4.1	Influence of different feeding levels on performance	93
7.4.2	Reaction to high ambient temperature during the day and of alternating feeding levels	94

Dedication

Dedicated to the whole clan with its strong roots in Kalomo, Choma, Gwembe Valley and Namwala.
Dedicated especially to the children.

List of Abbreviations

ADF	acid detergent fibre
ADG	Average Daily Gain
ANOVA	Analysis of variance
ca.	Circa
Camer.	Cameroon
CP	crude protein
CV	Coefficient of variation
D	Day
DM	dry matter
DMI	dry matter intake
C1	1 st level of crossing = First filial generation
C2	2 nd level of crossing (C1 x C1)
H	High ambient temperature (31°C/50%RH)
GLM	General Linear Model of the SAS Institute
HL, LH	High-Low, Low-High Feeding
ht	High ambient temperature
K1	Kreuzungsstufe Nr. 1: Erste Filialgeneration
K2	Kreuzungsstufe Nr. 2: (K1 X K1)
L	Low ambient temperature (15°C/70%RH)
lt	Low ambient temperature
Lsm	least squares means
M	Maintenance
MLD	<i>Musculus longissimus dorsi</i>
MSM	<i>Musculus semimembranosis</i>
MLD-1.5	pH value of MLD 1.5 hrs post-mortem
MLD-24	pH value of MLD 24 hrs post-mortem
MSM -1.5	pH value of MSM 1.5 hrs post-mortem
MSM-24	pH value of MSM 24 hrs post-mortem
N	Number
N/A	not applicable
NDF	neutral detergent fibre
OM	organic matter
RH	Right Half (of carcass)
R-SQ	coefficient of determination
SE	standard error
Std	standard deviation
Wk	Week

1 Introduction

Increase in the human population and the scarcity of production resources exert severe pressure on the small scale mixed farming system that threatens its existence (PETERS and LAES-FETTBACK, 1995). Increasing demand for animal protein and the ever increasing competition for land resources call for major structural changes in the agricultural sector which is the major source of occupation, subsistence and income in the Tropics. A major objective of such changes will be to increase productivity per animal and per unit area.

With the threat of land degradation, rising demand in animal products should be met by an increase in animal productivity and not by further increase in animal numbers which means increased production per animal through changes in animal genotypes, better feeding and management (MALMFORS *et al*).

Small ruminants have an increasing role to play in areas where the availability of land and fodder is insufficient (HORST, 1981). They can utilise fodder resources high in crude fibre and present the advantage of high reproductive performance and a small body size that makes it feasible to adapt to extreme environmental conditions (PETERS, 1988).

By increasing small ruminant rearing and productivity, a still higher degree of integration can be achieved in the existing farming systems of the Tropics. The high productivity and low capital investment demand of small ruminant production ensures easy access to animal protein supply, higher liquidity of the smallholder enterprise and a ready supply of easily applied manure. Small ruminant production is a further strengthening of the socio-cultural institutions through its cultural relevance and religious function. KEZIE (1997) reports on the situation in Togo where sale of small ruminants (sheep and goats) is effected to meet family needs especially before the harvest, at the beginning of the new school year and in case of illness and where the preference of sheep as slaughter animals at religious ceremonies is more pronounced. Similar reports pertaining to the situation in Ghana and the importance of local sheep have been made by NGERE (1973) and LONDON (1993).

In drought areas, small ruminants are increasingly playing the role of bridging the gap between good years and drought years, years of plenty and years of hunger.

Besides being a means of supply of meat, milk, and hides, sheep production as a sub-sector of small ruminant production could form a basis of the major export trade as has been the case in Somalia where big livestock (cattle and camels) and small ruminants (sheep and goats) have made up to 80% of the national export trade with the latter numerically making up 75% of all animals (MUMIN, 1986). It has its own *specific role* within complex and diversified farming systems. The role of science is to bring this more to bear.

1.1 Statement of the problem

Constraints to increased sheep production in the Tropics and Subtropics are of a biological and environmental nature and relate to the available potential, survival in hot tropical environments, and required efforts to increase production.

Sheep production in the Tropics is constrained by the following factors:

1. Low genetic potential
2. Seasonality of availability of feed and scarce water resources
3. High ambient temperature

Most sheep breeds of the Tropics have not been selected for high productivity. This implies low rates of growth and long time to reach physiological maturity. Low milk yield of the ewes reduces the chances of the lambs to survive (BULLERDIEK, 1996).

To be able to survive in hot climates, animals should demonstrate the ability to consume and digest feed stuffs high in crude fibre content and to survive under conditions of seasonal feed availability, water scarcity, high heat and radiation while still retaining the ability to utilise the range (HORST and PETERS, 1983). Feed production, quality and availability are dictated by weather changes and thus take a seasonal pattern. Low productivity of tropical sheep races and seasonal availability of feed do not therefore offer the best combination for increased sheep production. Only fast growing sheep

strains with a higher rate of growth from birth to weaning could utilise seasonally available feed resources including crop by-products more efficiently. The natural ability of the animal to regain weight lost due to feed scarcity upon re-implementation provides the possibility for compensatory growth and recovery and efficient utilisation of scarce feed resources characterised by the same seasonal pattern.

Conditions of rearing that are free from thermal stress also generally yield the highest economic returns such that it would be in the interest of the producers to be aware of them and to take any necessary steps to provide the necessary climate in the shed and to select breeds or individuals of animals best suited to a given climatic area (BIANCA, 1961). The tropical environment might pose problems of a thermoregulatory nature and of survival for temperate strains (BIANCA, 1976) of sheep which have mostly been selected for higher productivity over a long period of time. The tropical climate and weather are both characterised by high ambient temperatures especially during the day. Cold nights and winds are a common feature in the dry part of the Tropics.

According to BIANCA (1971) knowledge in the area of bioclimatology of the farm animal needs to be extended to include the effects of such factors as age, sex, breed, level of feeding and level of performance to be adequate. It would then be possible to link theory with practice provided the behaviour of the animals under variable climatic conditions are studied and properly interpreted to solve related problems in the animal production sector.

Unlike field studies, experiments in the climate chamber have the advantage of reducing to a minimum the number of effective climatic factors as well as bringing under control or eliminating altogether non-climatic factors such as nutrition and husbandry and thus making it possible to identify causes and interpret results for practical use (BIANCA, 1971).

Thermoregulation covers all changes taking place in a given animal in response to thermal stress which enables the animal to maintain body temperature within normal limits for its species when exposed to cold or heat (BIANCA, 1977). Such changes are functional (e.g. shivering or sweating), structural (e.g. vlies type) or behavioural such as the search for a less hot micro-climate. Behavioural changes normally form the first pattern of response followed by physiological ones (*ibid.*).

In view of the long time it would take to select for high productivity within the local tropical sheep breeds and regarding the existing big gap between demand and supply of animal protein, the production of sheep crosses of temperate and tropical breeds becomes all the more relevant in an effort to increase productivity while retaining the ability of the animal to apply adequate thermoregulatory function.

2 Review of literature

2.1 Production performance of sheep with relevance to the tropics

2.1.1 Performance of mutton sheep breeds and their crosses under tropical conditions

2.1.1.1 Growth performance

It is generally accepted that crossbreeding local small ruminants in the Tropics with exotic breeds could contribute to increased animal productivity. MOHAN *et al.* (1985) recorded very significantly ($p < 0.01$) higher ADG in Nellore x Dorset crosses than in Mandya x Dorset ones. FERNANDES and DESHMUKH (1986) found significantly ($p < 0.05$) higher live body weight at weaning (90d) and at 180 days of age of Dorset x Deccani crosses than of the pure Deccani, Merino x Deccani or the C2 of both C1 genotypes. Feed efficiency was also significantly ($p < 0.05$) higher for the crosses with Dorset followed by those with Merino.

Among tropical breeds of sheep hair sheep are considered to have high potential to increase productivity under tropical conditions where animal protein is in short supply. Hair sheep (BRADFORDBRADFORD and FITZHUGH, 1983; PASTRANA *et al.*, 1983; ZARAZUA and PADILLA, 1983) and crosses between them and temperate breeds (GOODE *et al.*, 1983) are well adapted to the tropical environments. GOODE *et al.* (*ibid.*) recorded a rectal temperature in Barbados Blackbelly ewes of 0.7°C below that of the Dorset and Suffolk ones whereas that of their crosses was intermediate. The range of adaptation of hair sheep also includes tolerance to trypanosomiasis (ADEMOSUN *et al.*, 1983; BERGER, 1983) and worm infestation (GOODE *et al.*, *ibid.*).

There is immediate need to increase the productive performance of small ruminants in the Tropics which is very low at the moment. ARMBRUSTER and PETERS (1992) reported low adult live weights for Djallonke sheep and goats aged twenty-four (24) months of 21.8 kg and 18.1 kg, respectively. Average litter size was 1.19 lambs and 1.52 kids, respectively. Reproductive performance was however high with annual lamming and kidding rates of 173.6% and 234.1%, respectively. The trend was reported to be similar in West Africa for both types of small ruminants (*ibid.*).

Biological and economic efficiency of lamb production can be achieved first and foremost through increased reproductive rate i. e. by increasing the number and weight of the offspring of the breeding female (METZ, 1990). Biological improvements need to be accompanied by better management. KEZIE (1997) reported a 38% improvement in gross margin per ewe, of sheep reared under relatively improved management in Togo as being attributed to higher reproductive performance.

The higher performance of crosses of hair sheep with exotic breeds compared with pure hair sheep and expected adaptation could be further exploited to increase supply of animal protein in the Tropics. Crossing West African Dwarf with Blackhead Persian increased birth weight (2.3 ± 0.45 kg) of the crosses more than that of the locals (1.3 ± 0.23 kg) and pushed the adult weight of the ewes to 32 kg instead of 21 kg in the local and still within limits to survive under natural grazing conditions (NGERE, 1973). NGERE and ABOAGYE (1981) also found that the crossbred Nungua Black Head ewes produced very significantly ($p < 0.01$) heavier lambs that weighed 2.2 kg at birth than the pure West African Dwarf sheep (1.3 kg) although comparatively, the former had more single births than twins.

GATENBY *et al.* (1997) found that crosses of St. Croix and Barbados Blackbelly with Sumatra gave more productive C1 ewes which produced bigger lambs than the local Sumatra. Crosses with Barbados Blackbelly (2.10 ± 0.05 kg) and with St. Croix (2.03 ± 0.03 kg) had highly significant ($p < 0.001$) birth weight than the Sumatra (1.45 ± 0.04 kg).

FOOTE *et al.* (1983.) showed that crosses between St. Croix and Rambouillet achieved higher ADG than those of the pure St. Croix over a six week feeding period. However, the ADG of the pure Rambouillet was highest over the same period. GOODE *et al.* (*ibid.*) recorded significantly heavier birth weight of Dorset x Barbados Blackbelly crosses than those of Dorset, Dorset x Finnish Landrace and Rambouillet x Finnish Landrace crosses. Heavier birth weight was later followed by a higher ADG value. In another experiment, SHELTON (1983) recorded lowest ADG in Barbados Blackbelly x Rambouillet crosses compared with those of the Rambouillet and the Blackface x Rambouillet crosses. Nevertheless, Barbados Blackbelly x Rambouillet crossbred ewes had the biggest number of lambs weaned per ewe per year compared with the pure Rambouillet, Finnish Landrace x Rambouillet and the Karakul x Rambouillet. NURSE *et al.* (1983) have recorded highest litter size in the Barbados

Blackbelly ewes compared with the Creole and crosses between them. High litter size was, however, associated with high mortality (*ibid.*; DETTMERS, 1983) with about 66% of deaths taking place during the first week of lactation in the Barbados Blackbelly (ZARAZUA and PADILLA, 1983). Survival and growth are largely dependent on the milk yield of the ewes and is closely associated with birth weight, birth type and management (DETTMERS, *ibid.*). In some cases, survival and growth rate could be improved by crossbreeding (NURSE *et al.*, *ibid.*). For tropical conditions, the issue of survival needs to be given due attention.

The trend of the crosses to perform better than local animals has also been observed in goats as well under tropical conditions. Comparing the performance of Galla goats and their crosses with Anglo-Nubian, ABEBE (1996) also recorded higher growth rates for crosses at weaning than for the pure Galla both under conditions of natural pasture and/or occasional supplementation.

Table 1 shows the performance of hair sheep with regard to birth weight and Average Daily Gain. Comprehensive studies looking at both pre- and post-weaning performance of hair sheep and their crosses which also consider milk performance as an essential trait for lamb survival have been wanting in the tropics.

It is not clear if the matted coat of the C1 crosses produced by crossing hair sheep with wool breeds would allow for adequate adaptation to a tropical environment (BRADFORDBRADFORD and FRITZHUGH, 1983). On account of their new coat and vlies types, crossbred lambs may have a physiologically different pattern of reaction to high ambient temperature than pure hair sheep which may have serious implications for production.

Table: Birth weight and Average Daily Gain performance of hair sheep and their crosses

Breed/Cross	Birth wt., kg	ADG, g	Stage	Management	Zone/Country	References
West African Dwarf (WAD)	1.50 - 1.70	-	-	Free range	Humid Tropics	ADEMOSUN <i>et al.</i> , 1983
WAD	2.40	-	-	Station	"	ADEMOSUN <i>et al.</i> , 1983
WAD	1.60	-	-	"	"	DETTMERS, 1983
WAD	1.77	-	-	"	"	DETTMERS, 1983
WAD x PERMER	2.30	-	-	"	"	DETTMERS, 1983
WAD x PERMER	1.48 - 1.86	-	-	"	"	ADEMOSUN <i>et al.</i> , 1983
"Small Forest Sheep"	-	57 – 85	30 - 150d	"	"	VALLERAND/BRANCKAERT, 1975 quoted by DETTMERS, 1983
Djallonké	-	51 – 87	30 - 120d	"	"	BERGER, 1983
Djallonké	1.70	79	7 - 30d	"	"	BRADFORD, 1983
		44	30 - 90d			
Pelibuey	2.50	-	-	"	"	ZARAZUA and PADILLA, 1983
Peliguey	2.50	-	-	"	Pasture	GONZALEZ-REYNA <i>et al.</i> , 1983
Peul	-	124	0 - 40d	"	Arid Tropics	BRADFORD, 1983
		111	40 - 180d			
Touabire	-	146	0 - 40d	"	Arid Tropics	BRADFORD, 1983
		93	40 - 180d			
"Sahel"	3.0	84	0 - 180d	Sedentary	Arid Tropics	WILSON, 1983
Yankasa	3.75	-	-	-	"	FERGUSON, 1964, quoted by DETTMERS, 1983
Uda	3.75	-	-	-	"	"
Merino x Yankasa	3.80	-	-	-	"	"
Merino x Uda	4.20	-	-	-	"	"
Dorset x Barbados Blackbelly (BB)	3.4 0 - 3.90			Station	USA	GOODE <i>et al.</i> , 1983
BB x Dorset	-	200	post-weaning	"	"	GOODE <i>et al.</i> , 1983
Dorset x (Dorset x BB)	-	290	"	"	"	GOODE <i>et al.</i> , 1983
Suffolk x (Dorset x BB)	-	290	"	"	"	GOODE <i>et al.</i> , 1983
St. Croix	-	255	"	"	"	FOOTE, 1983
St. Croix x Rambouillet	-	292	"	"	"	FOOTE, 1983

2.1.1.2 Importance of vlies

The range of temperature conditions under which sheep are kept for the production of meat and wool is extremely wide, varying from subtropical to subarctic conditions (GRAHAM *et al.*, 1959). This may constitute an advantage with regard to any effort made to increase productivity by crossbreeding of various relevant genotypes and more especially those involving hair sheep. Nevertheless, the extent to which coat and vlies type of each new cross influences physiological reaction and therefore productivity needs due consideration. BLIGH (1959) came to the conclusion that panting in response to high ambient temperature was peripheral in origin thus highlighting the important role of peripheral thermoreceptors in thermoregulation.

Hair colour and density along with live body weight are some of the visible physical adaptations to environmental conditions (JOHNSON, H and RAGSDALE, 1960). PANT *et al.* (1985) found that the colour (black or white) of hairy sheep and goats under tropical conditions in Brazil did not influence mean rectal temperature; however, sheep had 8.55 more ($p < 0.001$) respirations per minute than goats. From the morning time to the afternoon, respiration rate increased ($p < 0.0001$) almost three times. Mean respiration rate for black animals was higher (43.31) than for white animals (38.30), a fact caused by large differences within goats (black and white) than within sheep.

Vlies is an insulation agent whose effectiveness is based on its ability to form a relatively stagnant layer of air around it which tends to block wind and thereby blocking the convection of warmth (BIANCA, 1971). Unlike solar radiation, wind lowers the level of the lower critical temperature (BIANCA, 1968). The most stressful combination of factors affecting this is that of low temperature, high wind and rain (BIANCA, 1976). The insulatory ability of vlies can be adversely affected (reduced) by strong wind and by water whose conductivity is twenty-four (24) times that of air (BIANCA, 1971).

Through standing vlies and change over from summer to winter vlies, the insulatory capacity of vlies is increased short-term and long-term, respectively. Seasonal changes in vlies characteristics are incited by a reduction in the photoperiod and by the lowering down of temperature which is more of a feature of the temperate regions than of the tropics (*ibid.*).

The growth of vlies varies between animals depending on the level of selection. Double coats with differential physical characteristics (i. e short finer undercoat and long coarse overcoat) typical of the Angora rabbit, cashmere goats, mink and wild sheep exhibit a seasonal pattern of moulting. Seasonal moult of vlies is a means to renew and modify its structure in order to adapt to seasonal climatic changes. Involved in the neuro-endocrine control of the growth and moulting of vlies are melatonin and prolactin, hormones secreted by the pineal body and the pituitary gland, respectively (ALLAIN, 1993; ALLAIN *et al.*, 1994).

A smooth hair coat with short, thick medullated hair is very effective in the reflection of solar radiation (BIANCA, 1976).

Under conditions of solar radiation, WALI and ASHIR (1990) recorded a significant rise in both skin and wool temperatures of Awassi sheep than in the shade that suggested that thermoregulation took place more through sweating than through panting.

2.1.1.3 Milk yield performance

Data on milk yield performance of hair sheep and their crosses is lacking. It is expected that sheep will exhibit a milk yield performance similar to that of goats such that their pattern of reaction can reasonably be compared.

Milk yield of the ewe is the main factor affecting lamb growth during the first few weeks of life (COOMBE *et al.*, 1960). Ewe milk yield and growth of the lamb are highly correlated during the 4 - 6 weeks of age (OWEN, 1957). OWEN (*ibid.*) also discussed a number of factors that influence the milk yield of the ewes that include level of nutrition, body weight of the ewe, age of the ewe, birth weight of the lambs, udder development and genotype of the ewe. Adequate good quality nutrition is essential during the late stages of gestation and during lactation. Milk yield tends to be positively correlated with body weight and also tends to increase in successive lactations as the ewe gets older. And under similar conditions of rearing and management milk yield of different breeds of sheep may be different. COOMBE *et al.* (*ibid.*) associated the later stages of lactation with deterioration in the temperament of the ewes to stand long enough to allow the lambs enough opportunity to suckle under field conditions.

METZ (1990) foresaw the high potential of synthetic breeds of tropical and temperate zone goats involving the Malaysian Katjang and German Fawn, respectively, in terms of increased mature live body weight, high growth rate and reduced antagonism between fecundity and rearing ability. It was recognised that the improvement of maternal performance through crossbreeding reduced this form of antagonism and was therefore especially important in small ruminants due to great variation in litter size and the fact that slaughter weight was largely attributed to maternal ability (BRADFORD, 1972).

There is therefore high potential to improve maternal performance and productivity through crossbreeding of local and temperate sheep breeds selected for high productivity. High milk yield of the ewe which is a pre-requisite for lamb survival and growth is the most important maternal improvement where lamb survival is especially low.

According to METZ (*ibid.*) dams with a mortality in their litter before reaching the age of 90 days produced about 39g less milk per day than those whose litter was intact but this difference was not significant. Crossbred dams were heavier at parturition than local dams and produced 71% more milk than the locals. There was therefore a higher rate of reduction in litter size from 0 - 90 days for the local than for the crossbred dams and for the first parity than for the second.

METZ (*ibid.*) also found that the milk yield persistency of the goats was significantly ($p < 0.001$) influenced by the environmental effect of parturition month. Measured as milk yield per unit metabolic post-partum weight of the dam, local goats showed higher decrease in milk yield per day of 16.5% during the first phase (0 - 34 days) of lactation than in the second phase (35 - 62 days) and the third phase (63 - 90 days) of lactation. Contrary to this, the crossbred (Katjang x German Fawn) goats showed a gradual increase in decrease of 10.8% and 15.1% during the first and the last two phases of lactation, respectively.

2.1.2 Effect of restricted feeding and realimentation on growth

2.1.2.1 Effect of restricted feeding

Feed restriction reflects seasonal availability of feed which is characteristic of the tropical environment. It is therefore necessary to know the impact of administration of any restriction on animals in general and on growing animals in particular.

Restricted feeding has been found to influence voluntary feed intake, digestibility of feed, growth rate, level of blood constituents and carcass value. Voluntary feed intake later during the first few weeks of realimentation has been found to be low after feed restriction (KEENAN *et al.* 1970). Restricted feeding caused increased digestibility (HADINOTO, 1984; MARAIS *et al.*, 1991) as a result of reduced rate of passage (MARAIS *et al.*, *ibid.*; Van BRUCHEM *et al.*, 1994). Lower nitrogen retention has also been associated with restricted feeding (THOMSON *et al.*, 1982).

Reduction in growth rate is inevitable due to reduced energy intake (SEARLE *et al.*, 1972; MARAIS *et al.*, *ibid.*; SEARLE *et al.*, 1982) and due to increased fat deposition (LEDIN, 1983; WRIGHT and RUSSEL, 1991; SEARLE *et al.*, 1982) especially in growing animals. In some cases, however, subcutaneous fat has been reported to have been lost (LITTLE and SANDLAND, 1975) or deposition of both protein and fat have been found to have reduced (HAYDEN *et al.*, 1993). All this has been reported to influence carcass quality. Where loss in weight was drastic, male animals have been found to be less tolerant to feed restriction than females (CAMPBELL, 1988; ABEBE, 1996; ALLDEN, 1968, 1979). Feed restriction resulted in considerable loss of water (DROUILLARD *et al.*, 1991), decreased blood constituents (SALEM *et al.*, 1989) such as glucose, growth hormones, insulin and thyroxin (NAQVI and KRAF, 1991; HAYDEN *et al.*, *ibid.*; CHOI *et al.*, 1997; PARK *et al.*, 1994; BURRIN *et al.*, 1990). Some organs like the liver, stomachs and intestines (LEDIN, *ibid.*; BURRIN *et al.*, *ibid.*; CARSTENS *et al.*, 1991; FOOT and TULLOH, 1977) tended to reduce in weight while others like the heart (WOLDEGHEBRIEL *et al.*, 1994) tended to increase under the influence of restricted feeding. Although physiological activity in the form of lowered heart and breathing rate has been reported by some workers (WALI and ASHIR, 1990) others reported improved feed efficiency with minimal restriction (WOLDEGHEBRIEL *et al.*, *ibid.*) while in another case (MARAIS *et al.*, *ibid.*) the same is reported to have been reduced. Gut fill has been found to increase as a result of restricted feeding (CARSTENS *et al.*, *ibid.*; TOUKOUROU 1997) due to increased consumption of straw (Van BRUCHEM *et al.*, *ibid.*).

In general, animals with higher genetic potential for lean tissue growth have been found to be more sensitive to nutritional stress than those of lower lean tissue potential (CAMPBELL, 1988).

2.1.2.2 *Effect of realimentation on growth*

Animals subjected to seasonal feed restriction may recover from loss of weight during the rainy season when pasture regenerates or when realimentation is administered. OSBORNE and MENDEL (1916) could show that 'under suitable dietary conditions lost weight may be regained far more rapidly than during normal growth through the same range of body weight.'

Compensatory growth is defined as increase in growth rate following nutritional restriction (RYAN, 1990; McMANUS *et al.*, 1972) and weight loss (THORNTON *et al.*, 1979). The mechanisms involved in compensatory growth include reduction in maintenance requirement, increased efficiency of growth and fattening, reduction in energy of tissue deposited and increase in feed intake. The effects of these mechanisms on compensatory growth depends on the severity and duration of restriction and the quality of feed during realimentation (*ibid.*).

Concluding that grazing animals are likely to be subjected to some degree of nutritional restriction that suggests that only about 50% of the growth potential of such animals is realised during the growing phase, RYAN (*ibid.*) gives an alternative definition of compensatory growth as follows:

Greater than normal growth rate sometimes observed following nutritional restriction that slows, only maintains or reduces the weight of the animals on which it is imposed for a sufficient enough period of time to allow for adaptation to the lower nutritive state.

The above definition tends to reflect the natural grazing environment characterised by seasonal feed restriction and the season(s) when feed is adequately available. Most cattle and sheep production systems dependent on pasture are subject to wide variations in the weight of the animals due to seasonal fluctuations in herbage production (GINGINS *et al.*, 1980). According to LEDIN (1983) compensatory growth can be used to concentrate growth to periods when feed is available at low cost especially in the Tropics following feed restrictions imposed by the dry season. SALEM *et al.* (1989), however, point out that for animals reared under extensive conditions in developing countries feed scarcity often experienced during the dry season and during times of drought cannot be counteracted by supplementary feeding because of the scarcity and high prices of concentrated feeds, thus making it largely uneconomical. Nevertheless, prevention of drastic losses in body weight would be desirable. It would be uneconomical to administer supplementary feeding in order to gain weight (FOOT and TULLOH, 1977). The need to minimise costly supplementation implies a necessity to estimate feed requirements for alternative growth patterns (GRAHAM and SEARLE, 1975).

Recurrent quantitative and qualitative seasonal deficiencies in feed supply causing undernutrition and numerical losses of animals are more serious when associated with prolonged droughts (ALLDEN, 1979).

To be put into practice, the ideas mentioned above would demand as pre-requisite, the following:

1. Knowledge of the level of seasonal feed restriction imposed on the animals by a given environment.
2. Exact knowledge of the mechanisms of compensatory growth well enough to be able to intervene in time to counteract the adverse effects of seasonal feed restriction.
3. Felt need to make feed/energy savings in areas not generally affected by seasonal feed restriction.

Compensatory growth may be complete, partial or absent especially in animals in which restriction is imposed soon after birth or at maturity (RYAN, 1990). The duration of compensatory growth would appear to be directly proportional to the level of restriction. Increasing the severity of restriction is more likely to result in compensatory growth being maintained for longer rather than its magnitude being further increased (ALLDEN, 1968; RYAN, *ibid.*). The exact nature of the relationship between the severity of restriction and the degree of compensatory growth is, however, not clearly understood (RYAN, *ibid.*). According to McMANUS *et al.* (1972), the physiological basis of compensatory growth still remains obscure.

The question must also be answered: What is the biological potential of compensatory growth and to what extent could a given level of restriction be justified? It is clear from the above mentioned that

severe restriction may not match the natural ability of the animal to exhibit compensatory growth within the same length of time that restriction took place. It therefore becomes necessary to 'bring the negative balance forward' such that, theoretically at least, the mechanism of compensatory growth is seen as having a strong time element. Since the possibility of intensifying the restriction does not always result in any proportionate increase in compensatory growth, to 'bring the negative balance forward' could be costly in terms of time and the feed input.

Existing knowledge of the phenomenon of compensatory growth is too insufficient to allow for its control and exploitation for the efficient production of desirable leaner carcasses from meat producing animals (THORNTON *et al.*, 1979). THOMSON *et al.* (1982) mention that increased appetite and the associated gut fill of animals previously subjected to feed restriction constitute an important factor responsible for compensatory growth.

According to HOGG (1991) compensatory growth lacks a definition that is 'precise, unambiguous and generally accepted' and views it as the ability to 'catch up' to better fed counterparts. It can at best be described as significantly higher rate of growth per day than an animal fed *ad libitum* exhibits above that of a genetically identical animal after a period of nutritional stress. Compensatory growth does not invariably occur following some period of nutritional stress or reduced live weight gain. HOGG (*ibid.*) therefore points out that whereas many trials discuss compensatory growth, the trend has been in fact to report on faster growth rate after a period of restriction because of improved feeding i. e. without any evidence of true i. e. complete compensatory growth.

There is no consensus regarding the causal involvement of the generally accepted mechanisms of compensatory growth (THOMSON *et al.*, 1982) and the factors responsible for inducing it remain undefined (HAYDEN *et al.*, 1993). Neither are the mechanisms by which the so-called stair-step growth influences mammary development and subsequent lactation known (CHOI *et al.*, 1997).

The direction of causality may be difficult to determine in many cases where emphasis is laid on the 'quantitative relationships between two or more variables' unless time is considered as an independent variable (FORBES, 1988). The review of literature on growth following realimentation has therefore also tried to reflect on the mechanisms that try to explain this kind of growth, while watching out for any reference to the element of time.

Strong reference to time is also given by HOGG (1991) in the statement: 'The popular belief that compensatory growth is a unique phenomenon somehow different from normal growth, does not bear close scrutiny. Rather it should be viewed as a transitory period of time, following nutritional stress, during which an animal's homeostatic mechanisms respond to an increased availability of food. During this transition, large changes occur in hormonal and enzyme levels and activity, maintenance requirement intake and digestibility of food and composition, as well as in the use of partitioning of energy and protein.'

It would appear also from the available literature that the length of time within which maximal growth would be expected to occur following realimentation is far much less than expected. Sometimes as short as three weeks (HAYDEN *et al.* 1993 using crossbred steers); or four weeks (BUTTLER-HOGG, 1984; HOGG, 1991) or five weeks (TOUKOUROU, 1997) in small ruminants at least. FOOT and TULLOH (1977) recorded 30 - 68 days (i. e. about 4 - 9 weeks) in Angus steers such that the individual animals compensating at 30 days had the lowest voluntary feed intake.

Reduction in maintenance requirement: Reduction in maintenance requirement has been associated with changes in the weight of animals as well as changes in requirement that are naturally bound to occur over a given period of time. Reduction in the size of the digestive tract and liver (RYAN, 1990; BURRIN *et al.*, 1990; TOUKOUROU, 1997) and of live weight (SAUBIDET and VERDE, 1976) are directly associated with previous feed restriction (GINGINS *et al.*, 1980; RYAN, *ibid.*) such that reduction in maintenance requirement *per se* may not be sustained long enough during realimentation (GRAHAM and SEARLE, 1972; GRAHAM and SEARLE, 1975; DROUILLARD *et al.*, 1991). Reduction in maintenance requirement and faster growth rate during realimentation may therefore not be directly connected. In addition to this, it has been reported that maintenance requirement is not maintained constant (GRAHAM and SEARLE, 1972) over time even when live weight is maintained as much as possible constant (GRAHAM and SEARLE, 1975; FOOT and TULLOH, 1977) and voluntary feed intake and metabolic rate may change according to season of the year (HORTON, 1981; BLAXTER *et al.*, 1982; BLAXTER and BOYNE, 1982). Lower energy and N losses (GINGINS *et al.*, *ibid.*; THOMSON *et al.*, 1982) were attributable to the restriction phase.

Increased efficiency of growth and fattening: Growth rate has sometimes been known to occur at faster rate during realimentation even without any corresponding increase in feed consumed (DREW and REID, 1975c). Increased rate of growth and fattening during realimentation (PARK *et al.*, 1987; RYAN, *ibid.*; WRIGHT and RUSSEL, 1991; CHOI *et al.*, 1997) could be attributable to increased efficiency of protein and plasma-N utilisation (THOMSON *et al.*, *ibid.*; PARK *et al.*, *ibid.*). Consequently, increase in amount of water (KEENAN *et al.*, 1970;) and protein (CHOI *et al.*, *ibid.*) has been reported by some workers. Increased efficiency of growth and fattening has been seen as an effort to catch up (THORNTON *et al.*, 1979; HOGG, 1991) especially in cases where animals had lost weight during feed restriction (SAUBIDET and VERDE, 1976) or weight of liver and other internal organs had reduced in size (RYAN, 1990; BURRIN *et al.*, 1990; CARSTENS *et al.*, 1991; TOUKOUROU, 1997). It has therefore not been possible to divorce it completely from previous feed restriction (RYAN, *ibid.*) from which it is carried over and from the age of realimented animals (RYAN, *ibid.*; HOPKINS and TULLOH, 1985) or their body weight (CARSTENS *et al.*, *ibid.*). Maximum reaction has been associated with a feed restriction level of 50% of *ad libitum* and differences in reaction between male and female lambs have been observed in favour of the former (MARAIS *et al.*, 1991). Nevertheless, weight loss is not always a pre-requisite to efficient growth rate (THOMSON *et al.*, *ibid.*). Although some workers (VIMINI *et al.*, 1984) have reported that hyperplasia growth is completed during gestation, it is possible based on the results of other workers (CHOI *et al.*, *ibid.*) to conclude that this could be stimulated with the administration of Low-High feeding.

Reduction in energy of tissue deposited: Reduction in energy of tissue deposited associated with Low-High feeding (BUTTLER-HOGG, 1986; DREW and REID, 1975b) is thought to be the result of an inverse relationship between protein and fat deposition both during the early and later part of realimentation. Low-High feeding has resulted in increased deposition of protein and water (KEENAN *et al.*, 1970; McMANUS *et al.*, 1972; LITTLE and SANDLAND, 1975; LEDIN, 1983; CARSTENS *et al.*, 1991; WRIGHT and RUSSEL, 1991; HAYDEN *et al.*, 1993) especially to replace depleted reserves in the liver and intestines (RYAN, 1990). Indeed faster gain in protein deposition during realimentation may constitute no more than mere response to redress changes taking place in the body during feed restriction (HOGG, 1991). Feed restriction levels below 50% of *ad libitum* may result in protein deposition being slowed down (see MARAIS *et al.*, 1991) probably due to loss of energy in urine (DREW and REID, 1975c), hence suggesting that extremes of feed restriction could be counterproductive. Replacement of depleted reserves implies the preference of protein and water deposition during the early part of realimentation (DREW and REID, 1975a; LEDIN, 1983; THOMSON *et al.*, 1982) and as long as rapid regain of liver and gut had to be achieved (LEDIN, *ibid.*). Some workers (THORNTON *et al.*, 1979; DREW and REID, 1975b) could therefore not find any significant difference in final carcass composition (protein, water, fat and ash) between lambs of High-Low and Low-High treatments. Fat deposition is associated with slow down in growth rate (BUTTLER-HOGG, *ibid.*). Intramuscular, subcutaneous and kidney fat was found to increase very significantly with High-Low than with Low-High feeding (BUTTLER-HOGG, *ibid.*). Loss followed by regain of body weight as implied in Low-High feeding caused considerable reduction in carcass fat composition compared with feeding to maintain constant weight (DREW and REID, 1975b). Percentage loss of fat was higher in the offal than in meat (THORNTON *et al.*, 1979). Thus reduction in energy of tissue deposited could be accounted for by increased protein deposition or break down of fat *per se* or a combination of both.

Increase in feed intake: Realimentation has generally been associated with increased feed intake which at the end of experimentation was lower, higher or equal to *ad libitum* feeding. Increased intake (GRAHAM and SEARLE, 1975; THORNTON *et al.*, 1979; PARK *et al.*, 1987; NAQVI and KRAF, 1991; PARK *et al.*, 1994) is the result of a big appetite (DREW and REID, 1975c) and has therefore been seen to be influenced by the level of restriction to which realimented animals were previously subjected to (SAUBIDET and VERDE, 1976). Animals allowed to first lose weight and then regain it consumed less feed than those reared at constant weight (FOOT and TULLOH, 1977). Some workers (GRAHAM and SEARLE, *ibid.*; DREW and REID, 1975c; PARK *et al.*, 1994) have reported increase in feed intake of realimented animals above that of those subjected to *ad libitum* feeding. It is thought that in such cases, animals were first subjected to drastic weight loss. Total feed consumed by realimented animals may not be significantly different from that consumed by the *ad libitum* fed group (HADINOTO, 1984) since increased intake *per se* may be limited to the realimentation phase alone (PARK *et al.*, 1987). Since peak feed intake took place three weeks after administration of realimentation (KEENAN *et al.*, 1970; FOOT and TULLOH, *ibid.*; HAYDEN *et al.*, 1993) it is reasonable to expect that, initially, feed intake could be associated with increased digestibility (GRAHAM and SEARLE, 1975; HADINOTO, *ibid.*). Initially high feed intake at the beginning of realimentation reduced as body weight started to increase (MARAIS *et al.*, 1991).

It is for the most part difficult to draw a distinct line between the different factors said to be responsible for increased growth rate during realimentation: the role of one may just be a reflection of the beginning, progression or end of one and the same thing. For example reduced maintenance requirement reflects reduced body weight or organ size, reduced body weight or organ size must be quickly regained, regaining of normal organ size is basically a low energy input process, and doing this at a time when animals have previously been subjected to hunger implies high feed intake. Any reasonable and worthwhile approach to this subject should therefore consider its application to solve practical problems of management.

2.1.3 Physiological reaction to high ambient temperature

High ambient temperature has a negative effect on productivity. This negative effect is direct in the form of stress suffered by the animal and the diversion of energy from the purpose of production to regulation of body temperature and indirectly by affecting the availability of feed resources upon which production is dependent. The availability of feed resources has a seasonal pattern implying that they are quantitatively and qualitatively inadequate during some seasons of the year. All this raises the question of the feasibility of rearing crossbred lambs with regard to both survival and maintenance of high productivity. Whereas measurement of productive adaptability needs a long period of time to quantify, basic indication of the ability to survive can be deduced from the physiological reaction of animals subjected to high ambient temperature in a climate chamber.

2.1.3.1 Effect on body temperature

High ambient temperature in the tropics is a major constraint to rearing of high production animals from the temperate region (MISCKE, 1977; KLEIN, 1984; ZIEGLER, 1988; SCHAFFT, 1993). An animal has to maintain a stable state (homeostasis) of its internal environment (e.g. oxygen partial pressure, body temperature, osmotic pressure, pH value and concentration of electrolytes) in order to maintain normal function in spite of the constantly changing state of the physical environment outside (BIANCA, 1971, 1964). In thermoregulation, the adverse effects of climate and weather are compensated for as the animal reacts to maintain normal body functions, which involves considerable expenditure of energy that would otherwise be used for productive purposes (BIANCA, 1971, 1976, 1977). This involves panting, sweating, vasodilatation and -constriction, control of level of intensity of metabolic activity and red blood cell concentration (BIANCA, 1971, 1964). Frequent defecation has also been identified as another form of reaction in response to high ambient temperature (BEAKLEY and FINDLAY, 1955). Lower critical temperature (-3°C for sheep in general; 29°C at birth and 28°C if shorn) is the level of ambient temperature at which the organism will produce heat in order to prevent a fall in body temperature (BIANCA, 1971). Mean critical temperature has been found to be lower at maintenance than at fasting level of feeding BLAXTER and WAINMAN (1961). The higher the milk yield or fattening performance and consequently the higher the feed intake; and the thicker the coat cover and layer of subcutaneous fat, therefore the lower the level of lower critical temperature (BIANCA, 1968). GRAHAM *et al.* (1959), however, concluded that even closely shorn sheep had difficulties losing heat at ambient temperature levels above critical temperature.

With increasing ambient temperature, loss of heat from the body increasingly takes place through evaporation of water in the form of sweat and panting through the damp respiratory tract (BIANCA, 1968). Sweating, though increasing water intake, does not involve as much energy as panting and does not therefore interfere with feed intake, neither does it present any danger of respiratory alkalosis as panting does. Sweating can result in loss of nutrients (JOSHI *et al.*, 1968). It has also been reported (BIANCA, 1968) that unlike cattle, sheep and goats can only produce little amounts of sweat.

The effects of high ambient temperature have been measured on various species of animals which included many experiments involving sheep. High ambient temperature has been found to result in rise in rectal temperature (McLEAN, 1963; KLEIN, 1984; STELK, 1987; WALI and ASHIR, 1990; STEIN, 1991; KAISER, 1992; MULLER *et al.* 1994b), and low ambient temperature in a reduction in rectal temperature (STELK, *ibid.*). Initial reaction to high ambient temperature may be associated with higher rectal temperature than at later stages (BEAKLEY and FINDLAY, *ibid.*). Increase in relative humidity combined with high ambient temperature has also been associated with increase in rectal temperature (WHITTOW and FINDLAY, 1968; HIPPEN, 1979; STEIN, *ibid.*;). Rumen temperature has also been reported to rise with increase in rectal temperature especially in combination with increased metabolic rate as a result of a high level of feeding (STEIN, *ibid.*). Increased heat production at low ambient temperature of 15°C has been seen as response to increased energy requirement for the regulation of body temperature (KAISER, 1992). Heat stressed animals have shown increased

concentrations of cortisol (MULLER *et al.* 1994b); and decline in thyroid activity and thyroid hormone secretion (JOHNSON, H and RAGSDALE, 1960; FAICHNEY and BARRY, 1986) that may not be associated with any adjustment to high ambient temperature (YOUSEF *et al.*, 1967). High concentrations of prolactin have been associated with relief from heat stress (PETERS and TUCKER, 1978; FAICHNEY and BARRY, *ibid.*).

At 15⁰C ambient temperature, heat loss through vaporisation of water has been found to be normal in steers compared with 35⁰C (BLAXTER and WAINMAN, 1961). High ambient temperature has been associated with a reduction in the difference between inner body temperature and that of the extremities (WHITTOW, 1962; McLEAN, *ibid.*). Diurnally alternating ambient temperature may have the same effect as the mean of both extremes maintained constant (GROSSMANN, 1983). However, alternating warm-cold ambient temperature during the day and at night, respectively, had a compensatory rise in rectal temperature during the cold night accompanied by cardiac acceleration and declining skin temperatures, thus implying peripheral vasoconstriction (BIANCA and NÄF, 1977). The adverse effects of high ambient temperature may be clearly manifested between 11⁰⁰ - 15⁰⁰ hrs of the day (MULLER *et al.* 1994c; refer also to PANT *et al.*, 1985).

Table 2: Effects of increasing ambient temperature on the rectal and rumen temperature of wethers fed a low, average and high energy ration.

Temperature at 60%RH		Rectal temperature		
		Ration 1: Concentrate: Roughage:95:5	Ration 2: 20:80	Ration 3: 10:90
From	To	Increase/Decrease (°C)		
15 ⁰ C	30 ⁰ C	0.8	-	0.5
30 ⁰ C	35 ⁰ C	0.6	0.6	0.7
15 ⁰ C	35 ⁰ C	1.4	-	1.2
20 ⁰ C	30 ⁰ C		0.3	
20 ⁰ C	35 ⁰ C		0.9	
		Rumen temperature		
15 ⁰ C	30 ⁰ C	0.3	.	1.2
30 ⁰ C	35 ⁰ C	0.4	.	0.1
15 ⁰ C	35 ⁰ C	0.7	.	1.3
20 ⁰ C	30 ⁰ C	-	.	-
20 ⁰ C	35 ⁰ C	-	.	-

Source: Based on KAISER, 1992, Fig. 12, p. 55

There was a rise in rectal temperature with increase in ambient temperature independent of the level of feeding. Rectal temperature tended to be higher with a high raw fibre ration than with a high concentrated feed ration. The opposite was true with regard to rumen temperature and therefore reflect the high level of fermentation in animals that consumed more energy.

2.1.3.2 Effect on breathing rate

High ambient temperature has been known to affect breathing rate by accelerating it (McLEAN, 1963; HALES and WEBSTER, 1967; WHITTOW and FINDLAY, 1968; BIANCA, 1971; MIESCKE, 1977; KLEIN, 1984; FAICHNEY and BARRY, 1986; MATHERS *et al.*, 1989; STEIN, 1991; KAISER, 1992) by up to ten times or more; and by reducing it (BIANCA, 1971) if the amount of stress increased further. The first phase of reaction involving accelerated breathing is accompanied by reduction in tidal volume. The second phase in which breathing rate reduces is accompanied by increase in tidal minute volume and can cause death as a result of respiratory alkalosis when CO₂ has been removed from the lungs into the blood stream, thus causing blood pH to rise (BIANCA, *ibid.*). Accelerated breathing was mostly effective in reducing body temperature in the upper respiratory tract (HALES and WEBSTER, *ibid.*).

Increase in breathing rate may not be accompanied by any increase in rectal temperature at high ambient temperature (FAICHNEY and BARRY, 1986). Panting may not therefore be an exact response to high ambient temperature so as to balance heat production with heat loss and may serve only as an approximate means of adjustment (BLIGH, 1959). Panting may also not be an efficient means of increasing heat loss in hot dry climates where the air temperature is usually high since an increase in breathing rate is usually associated with some increase in respiratory ventilation, although this tends to be limited by a reduction in tidal volume (McLEAN, 1963).

Breathing rate may also be affected by feeding level, type of coat cover and psychological status of the animals. Breathing rate was found to be higher for the higher quality pellet diet than for the alkali-treated barley straw supplemented with urea, sulphur, minerals and vitamins (MATHERS *et al.*, *ibid.*). A higher roughage diet in the form of alfalfa has been confirmed to cause higher oxygen consumption by the portal drained viscera (gastrointestinal tract, pancreas, spleen and mesenteric fat) and liver of heifers than a concentrated feed of a similar concentration (REYNOLDS *et al.*, 1991).

From 15°C/60%RH to 35°C/60%RH ambient temperature, KAISER (1992) recorded highest increases in breathing rate if change in ambient temperature was administered in combination with a high fibre or a high concentrate ration.

For a given total loss of water from the body in the form of vapour, the presence or absence of a fleece did not influence breathing rate (BLAXTER *et al.*, 1959). Only sensible heat losses at levels of temperature above critical showed wide variations in breathing rate associated with fleece length. Sheep with fleeces were found to have very wide thermoneutral zones, unlike closely shorn ones (*ibid.*). And for excited sheep even in the resting state, considerable variability in breathing rate has been reported (HALES and WEBSTER, 1967).

Table 3: Effect of increasing ambient temperature on breathing rate of wethers fed a low, average and high energy ration

		Breathing rate (No. Per minute)		
Temperature at 60% RH		Ration 1:	Ration 2:	Ration 3:
		Concentrate:		
		Roughage:95:5	20:80	10:90
	15 ⁰ C	15	-	23
	30 ⁰ C	62	50	123
	35 ⁰ C	156	77	164
	20 ⁰ C	-	15	-
From	To	No. of times of increase above original level		
15 ⁰ C	30 ⁰ C	4.13	-	5.35
30 ⁰ C	35 ⁰ C	10.40	5.13	7.13
20 ⁰ C	30 ⁰ C	-	3.33	-

Source: Based on KAISER, 1992, Fig. 12, p. 55

At ambient temperature of between 15⁰C and 30⁰C increasing the energy content of the diet was accompanied by an increase in breathing rate. At 35⁰C both extremes of diet i. e. high fibre content diet and high concentrated feed diet recorded much higher levels of breathing rate than for the average diet treatment, in that order. Raising the ambient temperature from 30⁰C to 35⁰C caused a more than 10-fold and 7-fold increase in breathing rate of wethers fed the high fibre and high concentrated feed diets, respectively.

2.1.3.3 Effect on feed intake and digestibility

Feed and water intake: Feed intake forms the basis of production such that a thermostatic regulation of intake (increase and reduction of appetite in the cold and heat, respectively) under extreme climatic conditions becomes an important point for animal production (BIANCA, 1971). High productivity is associated with a high metabolic rate and hence high heat production (BIANCA, 1976). Heat induced reduction in appetite is therefore useful as a mechanism of thermoregulation with the disadvantage that this implies loss in production (*ibid.*). High ambient temperature is known to cause reduction in feed intake (DAVIS and MERILAN, 1960; STELK, 1987; KAISER, 1992;) but increased digestibility due to reduced rate of passage (DAVIS and MERILAN, *ibid.*; BLAXTER and WAINMAN, 1961; McDOWELL *et al.*, 1969; FAICHNEY and BARRY, 1986; STEIN, 1991) and therefore reduction in energy lost in faeces (GRAHAM, 1959); as well as increase in water consumption (McDOWELL *et al.*, *ibid.*; KLEIN, 1984; FAICHNEY and BARRY, *ibid.*; STELK, 1987) and frequency of consumption (MIESCKE, 1977). On the other hand, low ambient temperature has been known to increase feed intake (KLEIN, *ibid.*) followed by reduction in digestibility (CHRISTOPHERSON, 1976; KENNEDY and MILLIGAN, 1978; KENNEDY *et al.*, 1978) and N-balance (BAILEY, 1964). A combination of low ambient temperature and high fibre ration has been associated with a negative balance of both N and energy (KAISER, *ibid.*). Further, sheep are said to be able to better tolerate high ambient temperature than cattle with regard to loss of appetite due to low metabolism per unit surface area (BLAXTER and WAINMAN, *ibid.*). The effect of ambient temperature on digestibility has not been found to be lineal (STEIN, 1991).

Table 4: Effect of increasing ambient temperature ($^{\circ}\text{C}$) on DM and raw fibre intake

Temperature at 60% RH		DM intake (%)		
From	To	Ration 1: Concentrate: Roughage:95:5	Ration 2: 20:80	Ration 3: 10:90
15 $^{\circ}\text{C}$	30 $^{\circ}\text{C}$	-10.81	-	-4.98
30 $^{\circ}\text{C}$	35 $^{\circ}\text{C}$	-11.30	-12.85	-4.44
20 $^{\circ}\text{C}$	30 $^{\circ}\text{C}$	-	-2.95	-
20 $^{\circ}\text{C}$	35 $^{\circ}\text{C}$	-	-15.42	-
15 $^{\circ}\text{C}$	35 $^{\circ}\text{C}$	-20.89	-	-9.20
From	To	Raw fibre intake (%)		
15 $^{\circ}\text{C}$	30 $^{\circ}\text{C}$	-15.26	-	-10.00
30 $^{\circ}\text{C}$	35 $^{\circ}\text{C}$	-14.91	-13.33	-1.59
20 $^{\circ}\text{C}$	30 $^{\circ}\text{C}$	-	-8.16	-
20 $^{\circ}\text{C}$	35 $^{\circ}\text{C}$	-	-20.41	-
15 $^{\circ}\text{C}$	35 $^{\circ}\text{C}$	-27.90	-	-11.43

Source: Based on KAISER, 1992, Fig. 3, p. 30

The above table shows that both DM and raw fibre intake were negatively affected by high temperature. The reduction in intake of raw fibre was generally higher than for DM. The reduction in intake of both nutrients was lower for Ration 3 than for 1 and 2.

2.1.3.4 Effect on production

High ambient temperature has been associated with a reduction in growth rate and milk yield. Data on growth performance of lambs under high ambient temperature in experiments in the climatic chamber is limited in terms of how it affects various genotypes. Data on milk performance has largely been concerned with dairy cattle. The physiological reaction of cattle in this case could be comparable to that of sheep subjected to similar conditions.

From 15 $^{\circ}\text{C}$ /60%RH to 30 $^{\circ}\text{C}$ /60%RH constant ambient temperature, 55% reduction in ADG has been reported and associated with 38% reduction in energy intake (STELK, 1987). In this case, two-thirds of the lambs reared at 30 $^{\circ}\text{C}$ /60%RH were prematurely removed from the experiment for failing to meet the minimum growth requirement of 50g Average Daily Gain. The same lambs recorded an average of 0.4 $^{\circ}\text{C}$ higher rectal temperature than those retained.

High ambient temperature has been associated with decline in milk yield (JOHNSON *et al.*, 1960; SCOTT and MOODY, 1960; WAYMAN *et al.*, 1962; MIESCKE, 1977; RODRIQUEZ *et al.*, 1985; KLEIN, 1984; BURMEISTER, 1988; ZIEGLER, 1988) especially in late lactation (JOHNSON *et al.*, *ibid.*). Decline in milk yield was the result of reduced feed intake (WAYMAN *et al.*, *ibid.*; MIESCKE, 1977) and reduced efficiency of utilisation (WAYMAN *et al.*, *ibid.*) and could be accompanied by loss in weight (BURMEISTER, *ibid.*) and reduction in fat content (ZIEGLER, *ibid.*). At high ambient temperature, interaction with feeding level was increased with regard to milk yield and quality and the physiological reaction of dairy cattle (SCOTT and MOODY, *ibid.*; LEIGHTON and RUPEL, 1956; WAYMAN *et al.*, 1962). At ambient temperature of between 15 $^{\circ}\text{C}$ and about 22 $^{\circ}\text{C}$, milk yield was less sensitive to variation (CUMMINS *et al.*, 1992).

High milk yield under high ambient temperature conditions was associated with low body temperature and high sweating rate (KLEIN, 1984). At about 40°C, high productivity was associated more with high energy deposition in the form of fat due to heavier body weight and higher chronological age (ZIEGLER, 1988). Earlier, JOHNSON *et al.* (1960) noted that potentially high and average milk yielding dairy cattle may demonstrate similar performance at an extreme ambient temperature level of 90°F/50%RH.

3 Main findings from survey of literature and objective

The comparison of results from literature and their interpretation is complicated by the different species, breeds and sometimes the sex of animals used as well as the type, duration and intensity of the treatment administered. Nevertheless, the following short summary of literature reflects to some extent the basic relevant points:

1. Crossbreeding of tropical sheep with exotic breeds selected for high performance could increase productivity under tropical conditions (MOHAN *et al.*, 1985; FERNANDES and DESHMUKH, 1986; NGERE, 1973; NGERE and ABOAGYE, 1981; GATENBY *et al.*, 1997; FOOTE *et al.*, 1983; GOODE *et al.*, 1983; SHELTON, 1983; NURSE *et al.*, 1983).
2. Crossbreeding could especially increase the survival and growth rate of the lambs (NURSE *et al.*, *ibid.*).
3. Hair sheep and their crosses do not only show high fertility but are adapted to the tropical environment as well (BRADFORDBRADFORD and FRITZHUGH, 1983; PASTRANA *et al.*, 1983; ZARAZUA and PADILLA, 1983; GOODE *et al.*, *ibid.*; ADEMOSUN *et al.*, 1983; BERGER, 1983).
4. It is not clear to what extent crosses produced by breeding between hair sheep and wool breeds of temperate zone origin could adapt to the conditions of high ambient temperature in the tropics (BRADFORD and FRITZHUGH, *ibid.*).
5. The advantage in growth performance of C1 kids over the pure Somali ones was reflected more after weaning than during the lactation phase (ABEBE, 1996).
6. Restricted feeding has been associated with higher gut fill (CARSTENS *et al.*, 1991; TOUKOUROU, 1997) and lower weight of liver and intestines (BURRIN *et al.*, 1990; CARSTENS *et al.*, 1991; TOUKOUROU, 1997); and reduced plasma glucose concentration (BURRIN, *ibid.*; NAQVI and KRAF, 1991). It has also been associated with increased levels of growth hormone (DRIVER and FORBES, 1981; HAYDEN *et al.*, 1993;), plasma urea nitrogen and nonesterified fatty acids (HAYDEN *et al.*, *ibid.*); as well as with a reduction in concentration of calorogenic hormones. From being only a pathologically related phenomenon, previously, OSBORNE and MENDEL (1916) associated compensatory growth with nutrition and, consequently, with animal production. Upon realimentation, many workers have also reported that compensatory growth had occurred but the question of how this comes into being has remained evasive (refer to McMANUS *et al.*, 1972; THORNTON *et al.*, 1979; THOMSON *et al.*, 1982; RYAN, 1990; HOGG, 1991; HAYDEN *et al.*, 1993;) for a long time.
7. Thermoregulation to balance heat production with heat loss is a pre-requisite to the sustenance of the life of warm-blooded organisms (BIANCA, 1971). The parameters of rectal temperature, breathing rate and hormonal secretions are useful indicators of climatic stress as a result of adverse climatic conditions (MULLER *et al.*, 1994b). Panting may, however, not represent a direct response to high ambient temperature (BLIGH, 1959) such that its effects need to be supported by other more reliable parameters like rectal temperature, sweating and others. Thermoregulatory activity as a result of strong adverse effects of climate and weather involves use of energy which implies loss in production (BIANCA, 1971, 1976, 1977). With constant level of high ambient temperature, productivity is adversely affected above 30°C/40%RH (SCHAFFT, 1993). Over long periods of time, the homeorhetic effects of thermoregulation influencing food partitioning and mobilisation of body reserves set in (ZIEGLER, 1988; SCHAFFT, 1993). The effect of various combinations of temperature and relative humidity with regard to digestibility of feed, energy balance and rate of passage does not seem to be lineal and is therefore largely hard to predict (see STEIN, 1991; KAISER, 1992); the effect on growth and carcass is also not lineal (STELK, 1987). The change-over from day temperature to night temperature causes a compensatory increase in body temperature accompanied by cardiac acceleration and a reduction in skin temperature (BIANCA and NÄF, 1977).
8. High ambient temperature around 30°C has been associated with *decrease* in rate of passage of cell wall and lignin (STEIN, 1991); feed intake (STELK, 1987; KAISER, 1992) and more especially that of roughage; weight of liver, back and thinning (STELK, 1987); milk yield (BURMEISTER, 1988) and milk fat of dairy cattle (ZIEGLER, 1988). It has also been associated with a *rise* in rectal temperature independent of type of treatment and in

combination with extremes of diet high in either raw fibre or concentrated feed (KAISER, 1992); in breathing rate (STEIN, 1991; KAISER, 1992); and *increase* in weight of the heart (STELK, 1987). Ambient temperature level of 15°C has been associated with increased energy expenditure for thermoregulation (KAISER, 1992) and highest negative N-retention of -30.61% compared to 30°C (-10.64%) in adult wethers (*ibid.*).

This work tries to assess to what extent the rearing of crossbred lambs produced by crossing between Cameroon and German mutton and milk breeds could be justified under tropical conditions as a means of increasing productivity there. The productive performance of the crosses was compared with that of the pure Cameroon.

Also considered was the effect of diurnally fluctuating temperature with high temperature (31°C/50%RH) during the day and low (15°C/70%RH) during the night on the growth, feed intake and carcass quality of lambs exposed to specific tropical temperature level over a long period of time and involving a restriction to reflect seasonal availability of feed under tropical conditions.

In the literature, the non-linear effect of high ambient temperature on the reaction pattern of animals has been stressed. This raises the problem of predicting its effects under varying conditions of environment, rearing and management. The importance of paying particular attention to specific ambient temperature conditions with potential for increased animal productivity therefore becomes all the more relevant. This approach is briefly justified as follows:

1. It is production oriented and involves use of growing animals.
2. It involves the use of crossbred lambs foreseen as a basis for increasing productivity under tropical conditions and tries to assess the possibility of rearing under the same.
3. It is an effort to study the reaction pattern of weaned lambs to a specific tropical ambient temperature level and is in that context therefore closer to practice, considering as it does, the effects of temperature on a relatively long period of time.
4. It considers that the complexity of growth and specific alternating ambient temperature (on daily basis) has not received enough scholarship.

The objective of this work was to assess the pre-weaning growth performance of pure Cameroon and crossbred (C1 and C2) lambs, the milk yield performance of pure Cameroon and C1 (Cameroon X Mutton) ewes. It was also to assess the post-weaning productivity and physiological reaction of pure Cameroon and crossbred lambs subjected to different feeding levels at stall ambient temperature and at diurnally alternating ambient temperature in the climate chamber i.e. high ambient temperature during the day and low at night. The performance and reaction of the crossbred animals was compared with that of the pure Cameroon hair sheep. The work tries to give answer to the following questions:

1. What is the pre-weaning growth performance of pure Cameroon lambs and crossbred (C1 and C2) lambs produced by mating Cameroon rams onto German mutton and milk sheep?
2. What is the milk yield performance of pure Cameroon ewes and of C1 ewes produced by crossing between the Cameroon and German mutton breeds - using the indirect lamb suckling method?
3. What is the post-weaning growth performance of pure Cameroon and crossbred (C1 and C2) lambs subjected to varying levels of feeding under stall ambient temperature conditions?
4. What is the physiological pattern of reaction of pure Cameroon and crossbred (C2) lambs subjected to a high (31°C/50%RH) and low (15°C/70%RH) rhythm of ambient temperature in the climate chamber, during the day and at night, respectively, and during three (3) phases of feeding viz. alimentation, restriction and realimentation (High-Low-High)?

4 Materials and Methods

A summary of the experimental work done is given. The conditions of experimentation, some basic equipment used and methods of data analysis are also briefly mentioned.

Origin of the sheep used in the experiments: The sheep used for the various experiments are based on a herd of the Cameroon sheep and various breeds of German sheep. The Cameroon sheep are originally from Cameroon, West Africa. They have a small body size (males, 60 - 70 cm at the withers and weighing 40 -50 kg; females, 58 - 65 cm at the withers and weighing 30 - 40 kg), hardy, less demanding and suitable for paddock rearing. They have a hairy coat, brown in colour with a black belly, head and legs. Their head is long with small ears slanting forward. Ewes have no horns but the males have snail-like horns and a mane on the neck and breast. Unlike the German breeds of sheep, they are short-tailed (ANONYMOUS, 1992, Deutsche Kamerunschafzucht). Although all the Cameroon lambs used in the experiments were born and reared at the Animal Production Research Station in Dahlem, Berlin, the original herd at the station was bought from the Zoo in Berlin and from Büren and was genetically similar to those found in Cameroon.

In numerical terms, the German breeds of sheep were made up of 46% Texel and some Blauköpfiges Fleischschaf, Rauwolliges Pommersches Landschaf, Coburger Fuchsschaf, Braunes Bergschaf, Merino Landschaf and the German Milk Sheep. These and others were also reared at the Animal Production Research Station in Dahlem, Berlin. Whereas all C1 and C2 lambs used in the experiments were born and reared in Dahlem, their parents were either also born in Dahlem, or bought in from other breeding stations.

The C1 crosses were produced by mating between the rams of the Cameroon and ewes of German breeds of sheep mentioned above and more especially the Texel. The C2 crosses were obtained by mating C1 rams with C1 females. Numerically, forty-seven (47) percent of the C2 crossbreds were produced by mating Cameroon X German Milk Sheep C1 males and females.

In order to compare the pre-weaning and post-weaning growth performance of pure Cameroon and crossbred (C1 and C2) lambs reared on the ewe, and when subjected to different feeding levels and to high ambient temperature during the day with alternating feeding levels, respectively, and in order to compare the milk yield performance of pure Cameroon and C1 (Cameroon x Mutton) ewes, the following experiments were conducted:

List of experiments

1. Pre-weaning growth

- Duration: 12 weeks i. e. from birth to about 80 days of age

Animals used:	Cameroon:	9
	C1 (Cameroon x German):	31
	C2 (Cameroon x German):	27
- Duration: 12 weeks i. e. from birth to about 80 days of age.

Animals used:	Cameroon:	11
	C1 (Cameroon x German):	21
	C2 (Cameroon x German):	28

2. Milk yield of ewes

- Duration: 9 weeks

Animals used:	C1 ewes:	5
	The ewes were about 1 year old.	
- Duration: 11 weeks

Animals used:	Cameroon ewes:	8
	C1 (Cameroon x Mutton) ewes	9
	The ewes were aged 2 about years.	

3. Post-weaning growth

Reaction to different feeding levels

- Duration: 12 weeks

Animal material:	Cameroon lambs:	10
	C1 (Cameroon x Mutton) lambs:	10
	C2 (Cameroon x Milk) lambs:	10

The lambs were aged about 80 days.
- Duration: 12 weeks

Reaction to high ambient temperature and alternating feeding levels

Animals used:	Cameroon lambs:	5
	C2 (Cameroon x Mutton) lambs:	5

The lambs were aged about 70 days.

4. Carcass evaluation

- All lambs in the post-weaning growth experiments.

4.1 Comparative pre-weaning growth performance of lambs of different genotypes

The experiment compared the pre-weaning growth performance of the crossbred lambs reared on the ewe with those of the pure Cameroon lambs reared under similar conditions. In this way, the growth performance of the crosses could be studied at an early stage. Only lambs born in February and March were included in the analysis. Estimated live body weight and Average Daily Gain (ADG) was done for 30, 60 and 90 days of age and from 0 - 30, 30 - 60 and 60 - 90 days, respectively.

4.1.1 Animals used

A total of 127 lambs were made available for this experiment from birth to weaning at about 80 days. A total of 67 lambs were available in 1994 and 60 in 1995. Three (3) genotypes were represented namely, 19 Cameroon lambs, 52 C1 (Cameroon x Mutton) and 55 C2 (Cameroon x German) crossbred lambs. "German" breeds included both mutton and milk types.

4.1.2 Feeding

Lambs were introduced to *ad libitum* feeding with hay from ten (10) days of age and to concentrated feed (Type 047, Ströh, Hobbersdorf) at the rate of 200g per animal per day from fourteen (14) days of age. The energy content of the concentrated feed was at the level of 5.9 MJ ME/kg. All animals had free access to water.

4.1.3 Housing of animals

Lambs were housed in pens together with their mothers after birth and later reared outside on pasture during warmer months from May to July.

4.1.4 Management of experimental animals

The parameter measured was pre-weaning live weight. Weights were taken from birth to 80 days once every two weeks in 1994; and once per week in 1995. (Interpolation of missing values was made for the 1994 weights).

4.2 Milk yield performance of Cameroon and C1 ewes rearing lambs using the suckling method

The milk yield performance of the C1 (Cameroon x Mutton) ewes using the suckling method was compared with that of the pure Cameroon ewes during 11 weeks of lactation of which only the first 9 were considered in the analysis.

4.2.1 Animals used

Five (5) Cameroon ewes aged about 1 year in their first parity were available in 1994 for this experiment over a period of 9 weeks from about lactation week 3. In 1995 there were eight (8) Cameroon ewes aged about 4 years and in parity 1 - 3 and nine (9) C1 (Cameroon x Mutton) ewes

aged 2- 3 years in parity 2 - 3 available over a period of eleven (11) weeks from about lactation week 1. In the analysis, only data on milk performance in 1995 was considered up to 9 weeks of lactation.

4.2.2 Feeding

Ewes were fed on group basis at the rate of 200g of concentrated feed (Type 047, Ströh, Hobbersdorf) per animal per day and hay, *ad libitum*. Of the 200g concentrated feed fed per ewe per day, 100g including hay (*ad libitum*) was fed at 7⁰⁰ hrs and the rest with hay at 14⁰⁰hrs on group basis. The energy content of concentrated feed was at the level of 5.9 MJ ME/kg. Lambs used in the suckling method were introduced to hay from ten (10) days of age and to concentrated feed from fourteen (14) days of age. All animals had free access to water.

4.2.3 Housing of animals

Lambs were housed in pens or kept on pasture together with their mothers except during separation prior to milk recording.

4.2.4 Management of experimental animals

Milk performance was recorded indirectly using the suckling method, i.e. weight of the lamb after suckling minus weight of the lamb before suckling (WALLACE, 1948; OWEN, 1957; COOMBE *et al.*, 1960; METZ, 1990).

The time of suckling was 7⁰⁰ hrs in the morning, 13⁰⁰ hrs in the afternoon and 19⁰⁰ hrs in the evening. The evening before the day when milk yield was determined using the suckling method, the lambs were allowed to suckle after being separated from the ewes for six (6) hours, and then separated again until the next day. This was to maintain equilibrium in the udder (METZ, 1990). Any ewe refusing to be suckled was restrained and made to do. The ewes were weighed at the beginning of the experiment and every four (4) weeks thereafter in 1994; in 1995 ewes were weighed every 14 days: twenty-four (24) hours before the day of suckling and on the day of suckling itself.

Suckling time was five (5) minutes (METZ, *ibid.*). In 1994, suckling was done at the rate of one ewe at a time. In 1995, suckling was done on group basis after individual weighing of the lambs before and after. This is based upon the behaviour of the animals and the experience of the previous year: no loss of weight by defecating or urinating (except for one case) and the nervous behaviour of the Cameroon ewes which made it necessary to leave them in peace during the time of suckling.

The following parameters were measured:

Milk yield performance: Weekly measurements were made in 1994. In 1995, each genotype was recorded for milk yield every 14 days: the C1 ewes were weighed in the first week and the Cameroon ewes in the following week. Measurements started and ended a week later in the Cameroon ewes than in the C1 (Cameroon X Mutton) ewes because of the relatively younger age of their lambs at the time of starting the experiment.

Live weight: The live weight of the ewes was recorded every month in 1994; every 14 days in 1995 and once before the day of milk recording and once on the day of milk recording.

4.3 Comparative post-weaning growth performance of lambs of different genotypes

4.3.1 Influence of different feeding levels

This experiment compared the post-weaning performance of pure Cameroon lambs subjected to High-Low and Low-High levels of feeding with that of the C1 (Cameroon x Mutton) and C2: (Cameroon x Milk) X (Cameroon x Milk) crossbreds. In a practical situation where feed availability is seasonal, and lamming aseasonal, it reflects the effects of limited access to feed at weaning followed by a period of plenty and vice versa.

4.3.1.1 Animals used

Thirty lambs i.e. 10 Cameroon, 10 C1 (Cameroon x Mutton) and 10 C2 (Cameroon x Milk) weaned at about 80 days of age were assigned to two equal treatment groups of fifteen (15) each. Both the Weißes Ostfriesisches Milchschaaf and Braunes Ostfriesisches Milchschaaf were used as ewes to produce the C1 with the Cameroon. All crosses were twins with one twin being assigned to treatment

group 1 and the other to treatment group 2 in order to balance genetic composition.

4.3.1.2 Feeding

Feeding was done twice per day at 7⁰⁰ hrs in the morning and at 15⁰⁰ hrs in the afternoon using concentrated feed (Type 046, Ströh, Hobbersdorf) with an energy level of 11.85 MJ ME/kg (SCHAFFT, 1993) and wheat straw with a level of energy estimated at 5 MJ ME/kg.

Conditioning lasted for one week. One group (1) of lambs was subjected to High-Low feeding with concentrated feed i. e. *ad libitum* feeding during the first 6 weeks followed by feed restriction (1.5 x maintenance) during the last 6 weeks of the experiment. The other group (2) was subjected to Low-High feeding by reversing the conditions of feeding in group 1, i. e. feed restriction (1.5 x maintenance) during the first 6 weeks followed by *ad libitum* feeding with concentrated feed during the last 6 weeks. Maintenance was calculated on the basis of 0.45 MJ ME/kg^{0.75} (ARC, 1980) supplied by the concentrated feed.

Wheat straw was supplied at a fixed rate of 200g per day per lamb for both groups. Feeding of both concentrated feed and straw was done twice daily in two equal portions at 7⁰⁰ hrs in the morning and at 15⁰⁰ in the afternoon. Water was made available at all times for *ad libitum* consumption.

4.3.1.3 Housing of animals

The first group on High-Low feeding treatment was reared individually in cages of about 1.18m² area at stall ambient temperature conditions. The second group on Low-High feeding treatment was reared separately in individual cages of about 1.57m² area at stall ambient temperature conditions.

An element of confounded effects owing to the separate housing of the lambs of both groups might have set in.

4.3.1.4 Management of experimental animals

Animals not being subjected to restriction of concentrated feed plus a fixed (200g per animal per day) amount of wheat straw, were supplied with the same at an incremental rate of 50g per animal if the amount of feed (concentrated or wheat straw) at a given level were completely eaten up over a period of two days (SCHAFFT, 1993).

A sample of the straw fed to the lambs was taken daily and stored in plastic bags for the determination of dry matter as mixed 14 day samples. Leftover straw was collected for each lamb for the same purpose. Pre-drying of straw was done in an oven for twenty-four hours at a temperature of 60°C and then for a further twenty-four hours at 105°C.

Parameters measured were as follows:

Live weight: Live weight was recorded twice per week before the morning feeding at 7⁰⁰ hrs.

Feed and water intake: Feed intake and refusals were recorded every day; and water intake every week for group 2.

4.3.2 Reaction to high ambient temperature during the day and of alternating feeding levels

This experiment studied the influence of high (31°C /50%RH) ambient temperature during the day and low (15°C /70%RH) at night with alternating feeding levels (High-Low-High) on the post-weaning productive performance and physiological reaction of C2 (Cameroon X Mutton) crossbred lambs compared with that of the pure Cameroon. This is a reflection of high ambient temperature combined with seasonal feed restriction which is a common feature of the tropical environment.

The level of temperature and relative humidity used in this experiment is an approximation of that in the geographical area of The Republic of Zambia and is thus practically representative of a specific tropical ambient temperature. It is based on the *mean maximum* and *mean minimum* temperature for day and night, respectively, and the corresponding level of relative humidity during the months of August to November. The means were calculated from weather data from thirty-six (36) meteorological stations over a period of six (6) years from 1989 to 1994, inclusive. They represent the means of

extremes of high and low ambient temperature in this geographical area in the months of August to November, inclusive.

The period August to November is the hot dry period characterised by high ambient temperature during the day and cool nights. It is the period after the harvest, and then the winter period; the period of scarcity of feed and water, the period before the rainy season which starts in mid November to December. It is also the major period of lamming, kidding and calving. And with whirlwinds and frequent fires, it can be seen as a critical period for animal production during the course of the year.

4.3.2.1 *Animals used*

Ten (10) lambs weaned at about 70 days comprising five (5) Cameroon lambs and five (5) C2 (Cameroon x Mutton) crossbred male and female lambs reared in individual cages (1.18m²) in the climate chamber were used for this experiment.

4.3.2.2 *Feeding*

During the period of conditioning and throughout the experiment, feeding was done every day at 7⁰⁰ hrs in the morning and at 15⁰⁰ hrs in the afternoon.

The lambs were fed *ad libitum* with concentrated feed for a period of four (4) weeks, then restricted at a level of 1.5 times above maintenance for the next four (4) weeks and then finally realimented (*ad libitum*) in the last four weeks of the experiment. Feeding was done using concentrated feed (Type 046, Ströh, Hobbersdorf) with an energy level of 11.85 MJ ME/kg (SCHAFFT, 1993) and wheat straw with a level of energy estimated at 5 MJ ME/kg. Feeding of wheat straw was fixed at 200g per day per lamb. Water was made available at all times for *ad libitum* consumption. One week before the start of the experiment, the lambs were separated and fed at a rate of 200g concentrated feed and wheat straw *ad libitum* supplied as a bundle. Conditioning then followed for one week.

During the High phases of feeding of concentrated feed an incremental rate of 50g per animal was given if the feed was completely eaten up over a period of two days (SCHAFFT, 1993).

4.3.2.3 *Housing of animals*

Rearing was done in the climate chamber under controlled temperature and relative humidity: 31⁰C/50% RH during the day and 15⁰C/70% RH at night. The technical specifications (size and operational data) of the climate chamber as given by BBC York were as follows:

Area: 68.75m².
 Guaranteed technical performance:
 - Temperature: 15 - 35 ±1⁰C
 - Relative humidity: 30 - 80 ±5%
 - Fresh air throughput: ≤ 1000m³/h
 - Lighting: 16 lamps at 65 Watt each

4.3.2.4 *Management of experimental animals*

Animals were subjected to 12 hours of light and 12 of darkness. Light and 31⁰C/50%RH ambient temperature was administered from 6⁰⁰ hrs to 18⁰⁰ hrs. From 18⁰⁰ hrs to 6⁰⁰ hrs light was switched off and the climate chamber was set at 15⁰C/70%RH. To avoid any drastic change of ambient temperature, the lambs entered the climate chamber at 20⁰C/50% RH day temperature which increased to 25⁰C/50% RH on the second day and finally to 31⁰C/50% RH on the third day of the conditioning phase. The night temperature remained unchanged for the rest of the duration of the experiment. However, during Week 3 and the first day of Week 4, all measurements were done at 29⁰C/88% RH due to problems with the climate chamber.

A sample of the straw fed to the lambs was taken daily and stored in plastic bags for the determination of dry matter as mixed 14 day samples. Leftover straw was collected for each lamb for the same purpose. Pre-drying of straw was done in an oven for twenty-four hours at a temperature of 60⁰C and then for a further twenty-four hours at 105⁰C.

The following parameters were measured:

Live weight: Live weight was recorded twice per week before the morning feeding at 7⁰⁰ hrs.

Feed and water intake: Feed intake and refusals were recorded every day; and water intake once per week.

Rectal temperature and breathing rate: Measurement of rectal temperature and breathing rate was done at 12⁰⁰ hrs on each day of measuring i. e. after six (6) hours of high (31°C/50%RH) ambient temperature and five (5) hours after the morning feeding period and then at 20⁰⁰ i. e. after two (2) hours of low (15°C/70%RH) ambient temperature and five (5) hours after the afternoon feeding period in both cases in order to avoid heat released due to increased metabolic activity immediately after feeding. Measurement of rectal temperature and breathing rate was done both on daily basis and once per week. A digital thermometer (Hartmann) was used to measure rectal temperature and a timer to measure breathing rate per minute by counting the number of movements of the flanks. A total of 90 measurements of rectal temperature and 88 of breathing rate were taken per lamb during the day at 12⁰⁰ hrs and at night at 20⁰⁰ hrs.

4.4 Carcass evaluation

Each lamb used in the experiment was assigned to an individual cage at random and fed and watered individually. From the end of each feeding experiment to slaughter, each lamb was fed at the same rate per day as per the last day of each experiment. A carcass evaluation involving all lambs used in the experiments was done at the end of each experiment in order to compare carcass values between treatments and genotypes.

Objective of carcass evaluation: The objective of evaluating the carcass of slaughtered lambs in terms of the weight of muscle, fat and bones aimed to quantify the edible and therefore economically important parts of the carcass. It was also aimed at comparing the effects of specific treatments on the weight of edible parts and of some physiologically important organs of digestion and thermoregulation and to make a comparison in the performance of the pure Cameroon and the C1 and C2 crossbred lambs. Important carcass parts were cut using the system recommended by the Deutsche Landwirtschaftliche Gemeinschaft (DLG). Aspects of quality were also considered within the same context.

Animal material: All lambs subjected to the post-weaning growth experiments: 30 in 1995 and 10 in 1996.

Parameters of carcass evaluation: Lambs to be slaughtered were fasted twenty-four (24) hours before slaughter and only allowed water (*ad libitum*) during this time.

Weights of carcass, valuable cuts and organs; length measurements; and measurements of quality were done for each slaughtered lamb. One and half hours after slaughter, pH-measurement of the *musculus longissimus dorsi* (MLD) and *musculus semimembranosus* (MSM) was done using a pH-meter (pH-STAR, Rudolf Matthaeus, Poettmes) and then repeated after twenty-four (24) hours. Each such measurement was done twice in 1995 and 1996. Body organs were weighed upon slaughter except for the entrails which were emptied, cleaned and washed, drained and preserved in the cold room and weighed the following day. The cold room was maintained at about 0±5°C.

The femur, hindleg bone and the foreleg bone of the Right Half were weighed and their lengths and circumferences measured using a tape measure at the end of the day of slaughter.

The weight of the warm dressed carcass was taken on the day of slaughter and that of the cold dressed carcass on the following day. Measurements of the lengths of the hindleg, the rump (round the rump region with the tape measure passing below the tail), back and chest were done using a tape measure on the cold dressed carcass. Subjective qualitative measurements (points between 1 and 10) based on the shape and fat distribution of the carcass was done for subcutaneous fat distribution, arm, back and hindleg by the Institute's meat technologist. The Right Half of the cold dressed carcass was then cut into seven (7) valuable parts as follows: hindleg, breast, foreleg, thinning, back, middle, and neck. Using a transparency, the eye muscle area on the back (13th rib) was marked and a little piece of muscle cut off for determination of fluid content by pressing for five minutes on absorbent paper (No. 332 077, Schleicher & Shuell). The areas of the eye muscle (one drawing per animal) and that for fluid content (two samples per animal) were estimated using a planimeter (Type 34051, A. Ott, Kempton). Two measurements of the reflection score (Goefo) of the eye muscle area (13th rib) were

then done though limited to the year 1995. The seven (7) valuable parts were dissected to determine the weights of muscles, fat and bones.

4.5 Analysis of data

The analysis of data was done using the General Linear Model of the SAS software package Version 6.11 (SAS Institute 1990). Analysis of variance, means of the main effects with standard errors were calculated. The following basic models were used to analyse the experimental data:

4.6 Basic models of the experiments

Comparative pre-weaning growth performance of lambs of different genotypes

$$y_{ijkl} = \mu + \alpha_i + \beta_j + \chi_k + \delta_{ij} + \varepsilon_{ijkl} :$$

y_{ijkl} = Estimated live body weight, kg / Estimated ADG, g

μ = mean

α_i = effect of genotype, i

β_j = effect of year, j

χ_k = effect of sex, k

δ_{ij} = interaction effect of genotype and year, ij

ε_{ijkl} = error

Milk yield performance of Cameroon and C1 ewes rearing lambs using the suckling method

$$y_{ij} = \mu + \alpha_i + \varepsilon_{ij} :$$

y_{ij} = Milk yield of the ewe, g

μ = mean

α_i = effect of genotype, i

ε_{ij} = error

Comparative post-weaning growth performance of lambs of different genotypes

Influence of different feeding levels

$$y_{ijkl} = \mu + \alpha_i + \beta_j + (\chi)_{ij} + \delta_k + \varepsilon_{ijkl}$$

y_{ijkl} = Live body weight of the lamb, kg

μ = mean

α_i = effect of treatment, i

β_i = effect of genotype, j

$(\chi)_{ij}$ = interaction effect of treatment and genotype, ij

χ_k = effect of sex, k

ε_{ijkl} = error

Reaction to high ambient temperature during the day and alternating feeding levels

$$y_{ijk} = \mu + \alpha_i + \beta_j + \varepsilon_{ijk}$$

y_{ijk} = Live body weight of the lamb, kg

μ = mean

α_i = effect of genotype, i

β_i = effect of sex, j

ε_{ijk} = error

Physiological reaction to high ambient temperature

$$y_{ijk} = \mu + \alpha_i + \beta_j + \varepsilon_{ijk}$$

y_{ijk} = Rectal temperature ($^{\circ}\text{C}$) / Breathing rate (No./minute) of lamb

μ = mean

α_i = effect of genotype, i

β_i = effect of sex, j

ε_{ijk} = error

Carcass evaluation

Influence of different feeding levels

$$y_{ijkl} = \mu + \alpha_i + \beta_j + \chi_k + \varepsilon_{ijkl}$$

y_{ijkl} = Weight (g) of organs or carcass parts of lamb / Measure of carcass quality of lamb

μ = mean

α_i = effect of treatment, i

β_j = effect of genotype, j

χ_k = effect of sex, k

ε_{ijkl} = error

Reaction to high ambient temperature during the day and alternating feeding levels

$$y_{ijk} = \mu + \alpha_i + \beta_j + \varepsilon_{ijk}$$

y_{ijk} = Weight (g) of organs or carcass parts of lamb / Relative weight (%) / Carcass quality of lamb

μ = mean

α_i = effect of genotype, i

β_j = effect of sex, j

ε_{ijk} = error

5 Results

5.1 Pre-weaning growth performance of lambs

In the analysis of variance the main effects of genotype, year, sex and the interaction effect of genotype and year were considered as presented in Table 5. The model explains 0.46 - 0.63 of the variation. The coefficient of variation was about 15% for estimated live body weight and 19 - 22 % for estimated ADG.

Table 5: Results of ANOVA for birth weight and pre-weaning growth of lambs

Effect	DF	Body weight				Average daily gain			
		Birth weight	Day 30	Day 60	Day 90	0 - 30 days	30 - 60 days	60 - 90 days	0 - 90 days
Genotype	2	***	***	***	***	***	***	***	***
Year	1	ns	**	***	***	**	***	***	***
Sex	1	*	*	**	***	ns	**	***	***
Birth month	1	ns							
Gen x Year	2	ns	Ns	ns	**	ns	ns	***	**
R-SQ:		0.61	0.57	0.58	0.63	0.46	0.53	0.55	0.61
CV (%):		13.70	14.6	15.2	14.5	19.3	20.5	22.0	16.2

*** $p \leq 0.001$; ** $p \leq 0.01$; * $p \leq 0.05$; ns for not significant; DF Degrees of freedom

The effect of genotype and sex on birth weight was significant. There was also a significant ($p \leq 0.001$) difference in the birth weight of the crossbred lambs. There was a significant effect of genotype, year and sex on live body weight of lambs at all three ages considered. The interaction effect of year and genotype was only significant at 90d of age. The effect of genotype and year on ADG was significant over the whole 90d period and over the three phases considered. The effect of sex on ADG was only significant over the last two phases (30 - 60d and 60 - 90d) of pre-weaning growth. The interaction effect of genotype and year on ADG was only significant during the last (60 - 90d) phase of pre-weaning growth.

Table 6: Effects of genotype and sex on birth weight and pre-weaning live weight of lambs, , LSQ-means \pm se

	Birth weight, kg	Live weight (kg)			n
		Day 30	Day 60	Day 90	
Genotype					
Cameroon	2.3a \pm 0.10	6.6a \pm 0.34	10.8a \pm 0.57	15.1a \pm 0.74	19
C1	3.9b \pm 0.11	10.8b \pm 0.21	17.0b \pm 0.35	23.1b \pm 0.46	51
C2	3.4c \pm 0.10	10.8b \pm 0.22	17.8b \pm 0.37	24.6b \pm 0.48	47
Sex					
Male	3.5a \pm 0.17	9.7a \pm 0.22	16.0a \pm 0.37	22.1a \pm 0.47	50
Female	3.3b \pm 0.11	9.1a \pm 0.20	14.5a \pm 0.33	19.8b \pm 0.43	67

Different letters within columns indicate significant differences $p \leq 0.05$

Least Squares Means and standard errors of estimated live body weight at 30, 60 and 90 days of age and of estimated ADG from 0 - 30, 30 - 60 and 60 - 90 days are presented in Table 6 and Table 7, respectively. At 30, 60 and 90 days of age, the C1 and C2 crossbred lambs weighed significantly heavier than the Cameroon. The difference in estimated weight was not significant between the C1 and C2 crossbred lambs although the latter recorded heavier weights.

Male lambs weighed more than female ones during the period considered, however, a significant difference in estimated live weight was only recorded at 90 days of age.

Table 7: Effects of genotype and sex on pre-weaning average daily gain of lambs, LSQ-means \pm se

	Average daily gain (g)			n
	0 - 30 days	30 - 60 days	60 - 90 days	
Genotype				
Cameroon	142.8a \pm 9.93	142.1a \pm 9.77	142.7a \pm 9.97	19
C1	230.3b \pm 6.13	208.9b \pm 6.03	200.8b \pm 6.15	51
C2	245.1b \pm 6.47	235.6b \pm 6.36	226.3b \pm 6.49	47
Sex				
Male	212.8a \pm 6.33	208.7a \pm 6.23	205.0a \pm 6.35a	50
Female	199.4a \pm 5.75	182.4b \pm 5.66	174.8b \pm 5.77b	67

Different letters within columns indicate significant differences $p \leq 0.05$

The C1 and C2 crossbred lambs recorded significantly higher ADG (Average Daily Gain) than the Cameroon at 30, 60 and 90 days of age. The difference between the C1 and the C2 crossbred lambs was not significant but the C2 had higher means than the C1 from 0 - 30, 30 - 60 and 60 - 90 days.

The Average Daily Gain for the C1 and C2 crossbred lambs exhibited a declining trend from 0 - 30, 30 - 60 and 60 - 90 days whereas that of the Cameroon remained almost unchanged during the same period.

Male lambs gained more than female ones during the period considered, however, a significant difference in estimated ADG was only recorded from 60 - 90 days. As expected, both males and females exhibited a declining trend for Least Square Means of estimated ADG from 0 - 30, 30 - 60 and 60 - 90 days.

5.2 Milk yield performance of Cameroon and C1 ewes using the suckling method

The milk yield performance of the Cameroon and C1 (Cameroon X Mutton) ewes from 1 - 9 weeks of lactation are presented in Table 8. Milk recording was done using the indirect suckling method in which the lambs were weighed before and after suckling. The model explains 0.82 of the variation over the whole experimental period of 9 weeks. It explains 0.66 - 0.67 of variation during the first three (3) weeks of lactation. Thereafter up to Week 9, the model explains only 0.22 - 0.40 of the variation. During Weeks 7 and 9, the coefficient of determination tended to be stable at 0.39 and 0.40. Thus after the third week of lactation, the model could not explain most of the variation.

The coefficient of variation was about 22% over the whole experimental period of 9 weeks. During the first three (3) weeks, the coefficient of variation was 22 - 23%, thereafter rising to 43 - 48% up to week 9. Mean variation increased considerably after the third week of lactation.

Table 8: Results of ANOVA for milk yield performance of ewes

	Week					
	1	3	5	7	9	Total
Genotype	***	***	***	**	**	***
R-SQ	0.66	0.67	0.22	0.39	0.40	0.82
CV(%)	21.78	23.35	43.00	46.52	47.90	21.52

*** $p \leq 0.001$; ** $p \leq 0.01$; * $p \leq 0.05$; ns for not significant

The significant difference in milk yield performance between the Cameroon and the C1 (Cameroon X Mutton) ewes was very high during the first three weeks. Milk yield performance of the ewes was highly significantly affected by genotype over the whole experimental period up to Week 9, during Weeks 1 and 3 and during Week 5. During Weeks 7 and 9, the effect of genotype was very significant ($p \leq 0.01$).

The means and standard errors of the milk yield performance of the Cameroon and the C1 (Cameroon X Mutton) ewes are presented in Table 9. During the first three (3) weeks of lactation, the C1 ewes yielded about two times more milk than the Cameroon. Thereafter up to Week 9, the C1 yielded three times more milk than the Cameroon apparently due to an abrupt fall in the milk yield performance of the latter.

Table 9: Influence of genotype on milk yield performance of ewes during 9 weeks of lactation, means \pm se

	Week											
	1	3	5	7	9	Total						
	n	M \pm se, g	n	m \pm se, g	n	M \pm se, g	n	m \pm se, g	n	m \pm se, g	n	m \pm se, kg
Genotype												
Cameroon	5	820a \pm 86	7	771a \pm 118	7	514a \pm 67	6	433a \pm 117	7	457a \pm 71	8	40.95a \pm 3.64
C1	8	1450b \pm 113	9	1777b \pm 81	9	1689b \pm 175	9	1322b \pm 163	8	1400b \pm 159	9	107.57b \pm 6.77

Different letters within columns indicate significant differences $p \leq 0.05$

In general, the means thus reflect the superior milk yield performance of the C1 ewes compared with that of the pure Cameroon during the lactation period from 1 - 9 weeks.

Figure 1 shows the regression of the milk yield performance of the Cameroon and the C1 (Cameroon x Mutton) ewes during 1 - 9 weeks of lactation. The regression of milk yield over this period shows a very high intercept of 1667g per ewe per day for the C1 crossbred ewes compared with 865g for the Cameroon. This constituted about two times more milk yield performance by the C1 ewes compared with that of the pure Cameroon.

The rate of change, b, for the C1 ewes was negative (-28g per week) and lower than that of the Cameroon (-53 g per week). The milk yield performance of the Cameroon ewes was therefore less persistent than that of the C1 (Cameroon X Mutton) ewes during 1 - 9 weeks of lactation.

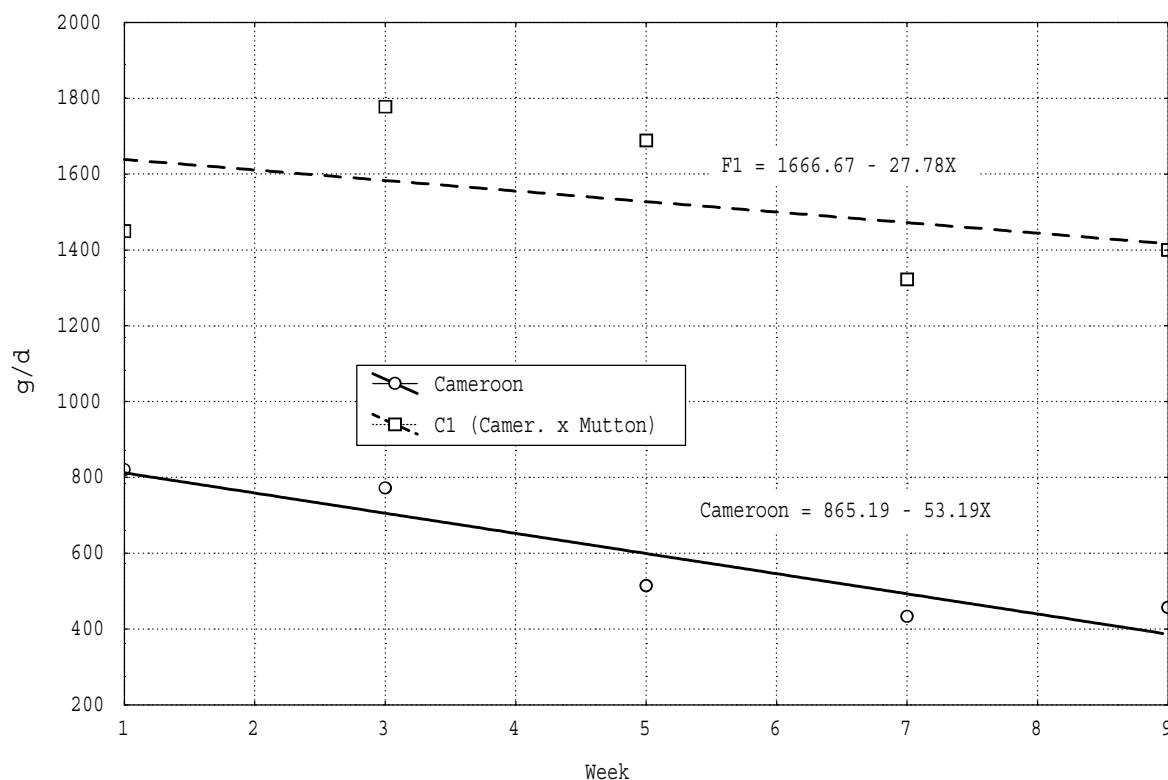


Fig. 1: Milk performance of Cameroon and C1 ewes during 9 weeks of lactation

5.3 Comparative post-weaning growth performance of lambs of different genotypes

5.3.1 Influence of different feeding levels on performance

The analysis of variance showing the effects of treatment, genotype and sex on live body weight, ADG, energy and feed intake of lambs per week and over the whole experimental period is presented in Table 10. In Table 11 means of live body weight, ADG, energy and feed intake during the same periods have also been presented.

Average Daily Gain: The model explains 0.73 of the variation for ADG over the whole experimental period. During 1 - 6 weeks, 0.47 of the variation is explained by the model, and 0.88 during 7 - 12 weeks. During the same period i. e. the overall period, 1 - 6 weeks and 7 - 12 weeks, the coefficient of variation was 17.27%, 33.81% and 19.15%, respectively. Thus the first six weeks recorded higher coefficient of variation compared with the second and last. There was also a very significant ($p \leq 0.01$) interaction effect of treatment x genotype during 7 - 12 weeks which is also reflected during Weeks 7 and 12. Further, this interaction can be associated with the Low-High phase of feeding whose High feeding phase proper was administered during 7 - 12 weeks.

The effect of treatment on ADG was highly significant over the whole experimental period, not significant during 1 - 6 weeks, and highly significant during 7 - 12 weeks. The effect of genotype on ADG was highly significant over the whole experimental period, very significant during 1 - 6 weeks, and significant during 7 - 12 weeks. The effect of sex on ADG was highly significant over the whole experimental period, and significant during 7 - 12 weeks. Lambs in the High-Low treatment ($91.59 \pm 6.89 \text{g/d}$) recorded significantly less ADG over the whole experimental period compared with those in the Low-High treatment ($128.10 \pm 7.06 \text{g/d}$). During 1 - 6 weeks, lambs in the High-Low treatment ($114.60 \pm 14.37 \text{g/d}$) recorded higher ADG than those in the Low-High treatment ($93.81 \pm 5.77 \text{g/d}$) even if the difference between them was not significant. During 7 - 12 weeks, lambs in the High-Low treatment ($68.57 \pm 5.77 \text{g/d}$) recorded less ADG than those in the

Table 10: Results of ANOVA for post-weaning growth, energy and feed intake of lambs

Effects	DF	Weeks														
Live body weight, kg		1	2	3	4	5	6	1 - 6	7	8	9	10	11	12	7 - 12	Total
Treatment:	1	Ns	ns	Ns	ns	Ns	ns	N/A	Ns	ns	ns	ns	ns	*	N/A	N/A
Genotype:	2	***	***	***	***	***	***	N/A	***	***	***	***	***	***	N/A	N/A
Sex:	1	Ns	ns	Ns	ns	Ns	ns	N/A	Ns	ns	ns	ns	ns	ns	N/A	N/A
Treat. X Gen.	2	Ns	ns	Ns	ns	Ns	ns	N/A	Ns	ns	ns	ns	ns	ns	N/A	N/A
R-SQ:		0.62	0.62	0.66	0.64	0.71	0.67	N/A	0.66	0.66	0.69	0.73	0.72	0.71	N/A	N/A
CV(%):		18.59	19.02	18.35	18.17	16.26	16.94	N/A	16.41	16.00	14.44	13.90	13.88	13.51	N/A	N/A
Average Daily Gain, g																
Treatment:	1							ns							***	***
Genotype:	2							**							*	***
Sex:	1							ns							*	***
Treat. X Gen.	2							ns							**	ns
R-SQ:								0.47							0.88	0.73
CV(%):								33.81							19.15	17.27
Feed/Energy intake per day																
Total energy intake, MJ ME/kg																
Treatment:	1	Ns	ns	Ns	*	***	***	*	Ns	***	***	***	***	***	***	ns
Genotype:	2	Ns	*	*	*	**	***	**	***	***	***	***	***	***	***	***
Sex:	1	Ns	ns	Ns	ns	Ns	ns	ns	Ns	ns	ns	*	ns	**	*	ns
Treat. X Gen.	2	Ns	Ns	Ns	ns	Ns	Ns	ns	Ns	ns	ns	ns	ns	ns	ns	ns
R-SQ:		0.31	0.40	0.35	0.37	0.61	0.67	0.50	0.55	0.68	0.71	0.80	0.85	0.86	0.82	0.63
CV (%):		17.59	17.96	23.72	25.01	20.75	20.02	18.81	15.40	14.67	13.91	13.99	12.39	13.10	11.80	13.15
Energy intake above M ₁ Factor																
Treatment:	1	Ns	Ns	Ns	ns	**	**	ns	**	***	***	***	***	***	***	*
Genotype:	2	*	*	Ns	ns	Ns	Ns	ns	Ns	*	ns	ns	ns	ns	ns	ns
Sex:	1	Ns	Ns	Ns	ns	Ns	Ns	ns	Ns	ns	ns	ns	ns	ns	*	ns
Treat. X Gen.	2	Ns	ns	Ns	ns	Ns	Ns	ns	Ns	ns	ns	ns	ns	ns	ns	ns
R-SQ:		0.33	0.41	0.17	0.19	0.38	0.41	0.20	0.45	0.80	0.68	0.65	0.82	0.86	0.83	0.28
CV (%):		18.45	11.41	20.30	22.17	20.11	19.10	16.55	10.92	8.15	10.71	12.42	8.81	8.45	6.95	8.99
Total DM intake, g																
Treatment:	1	Ns	ns	Ns	ns	**	**	ns	*	***	***	***	***	***	***	ns
Genotype:	2	*	**	*	*	***	***	**	***	***	***	***	***	***	***	***
Sex:	1	Ns	ns	Ns	ns	Ns	Ns	ns	Ns	ns	ns	ns	ns	**	*	ns
Treat. X Gen.	2	Ns	Ns	Ns	ns	Ns	Ns	ns	Ns	ns	ns	ns	*	ns	ns	ns
R-SQ:		0.35	0.44	0.37	0.38	0.61	0.66	0.51	0.58	0.66	0.69	0.79	0.84	0.86	0.81	0.65
CV(%):		17.66	17.23	21.68	22.07	18.98	18.12	17.40	13.64	13.61	12.41	12.32	10.79	11.32	10.53	12.13
DM Conc. feed intake, g																
Treatment:	1	Ns	Ns	Ns	*	***	***	**	Ns	***	***	***	***	***	***	*
Genotype:	2	Ns	*	Ns	ns	**	***	**	***	***	***	***	***	***	***	***
Sex:	1	Ns	ns	Ns	ns	Ns	Ns	ns	Ns	ns	ns	*	ns	**	*	ns
Treat. X Gen.	2	Ns	ns	Ns	ns	Ns	Ns	ns	Ns	ns	ns	ns	ns	ns	ns	ns
R-SQ:		0.28	0.39	0.33	0.39	0.63	0.69	0.51	0.52	0.70	0.73	0.79	0.84	0.84	0.82	0.61
CV(%):		17.51	18.56	25.68	27.61	22.27	21.61	19.15	16.92	15.44	15.09	15.64	14.18	15.40	12.90	13.96
DM Straw intake, g																
Treatment:	1	Ns	ns	*	***	***	***	**	*	*	***	***	***	***	***	ns
Genotype:	2	**	***	***	***	***	***	***	***	***	***	**	ns	ns	***	***
Sex:	1	Ns	ns	Ns	ns	Ns	Ns	ns	*	ns	ns	ns	ns	ns	ns	ns
Treat. X Gen.	2	Ns	ns	Ns	***	**	***	*	Ns	*	***	*	ns	ns	*	ns
R-SQ:		0.50	0.68	0.55	0.82	0.81	0.87	0.75	0.63	0.62	0.77	0.68	0.60	0.51	0.71	0.68
CV(%):		20.77	16.21	21.46	12.59	13.41	9.25	13.25	9.21	12.20	11.11	13.19	15.69	15.88	9.13	9.14

*** $p \leq 0.001$; ** $p \leq 0.01$; * $p \leq 0.05$; ns for not significant

Low-High treatment ($162.38 \pm 9.81 \text{g/d}$) following negative gain during Week 7 and the difference between them was significant.

The C1 ($123.69 \pm 8.80 \text{g/d}$) and the C2 ($116.43 \pm 8.55 \text{g/d}$) recorded significantly higher ADG than the Cameroon ($89.40 \pm 10.73 \text{g/d}$) over the whole experimental period. The difference between the C1 and the C2 crosses was not significant over the same period. During 1 - 6 weeks, the C1 ($116.67 \pm 7.36 \text{g/d}$) and the C2 ($123.10 \pm 8.14 \text{g/d}$) crosses recorded significantly higher ADG than the Cameroon ($72.86 \pm 17.57 \text{g/d}$). The difference between the C1 and the C2 crosses was not significant. During 7 - 12 weeks, the C1 ($130.71 \pm 18.78 \text{g/d}$) crosses recorded significantly higher ADG than both the C2 crosses ($109.76 \pm 22.44 \text{g/d}$) and the Cameroon ($105.95 \pm 11.83 \text{g/d}$). The difference between the C2 crosses and the Cameroon was not significant.

Thus from 7 - 12 weeks during which the High phase of the Low-High feeding level was administered, significant difference in ADG was attributable to treatment (feeding level), sex and the interaction effect of treatment and genotype unlike the case during 1 - 6 weeks when it was attributable to the effect of genotype alone. It is also noted that the C2 crosses recorded higher ADG than the C1 during the first six (1 - 6) weeks whereas the reverse was true and the difference significant during the second and last six (7 - 12).

Significantly higher ADG attained by the Low-High treatment compared with the High-Low treatment was largely (i. e. except during Week 7) associated with increased total energy intake during the High phase of feeding.

Intake of energy above maintenance: Lambs in the High-Low treatment (1.57 ± 0.04) consumed less energy above of maintenance than those in the Low-High treatment (1.70 ± 0.03) over the whole experimental period and the difference between the treatments was significant. During 1 - 6 weeks, lambs in the High-Low treatment (1.68 ± 0.08) consumed more energy above of maintenance than those in the Low-High treatment (1.49 ± 0.02) even if the difference between the treatments was not significant. The lack of any significant difference (except during Weeks 5 and 6) during this period was not expected. During 7 - 12 weeks, lambs in the High-Low treatment (1.46 ± 0.01) consumed less energy above maintenance than those in the Low-High treatment (1.91 ± 0.04) and the difference between the treatments was significant. Thus, the significantly higher ADG attained by the Low-High treatment compared with the High-Low one was also associated with higher energy intake above of maintenance level. Even if the effect of genotype on energy intake above maintenance was not significant over the whole experimental period and during 1 - 6 weeks and 7 - 12 weeks the Cameroon recorded the highest value over the whole experimental period followed by the C2 crosses and lastly by the C1 crosses (see Table 11).

Intake of wheat straw: Both during the first six and the second six weeks of the experiment, there was a significant ($p \leq 0.05$) interaction effect of treatment and genotype. During the first six weeks of the experiment, the interaction effect of treatment and genotype was highly significant ($p \leq 0.001$) between the Cameroon and the crossbred (C1 and C2) lambs. Between the C1 and C2 crosses, there was also a significant ($p \leq 0.05$) effect of treatment and genotype with regard to wheat straw intake during the first six (1 - 6) weeks of the experiment. During the second six (7 - 12) weeks of the experiment, the interaction effect of treatment and genotype between the Cameroon and the C1 crossbred lambs was highly significant ($p \leq 0.001$) whereas that between the Cameroon and the C2 was very significant ($p \leq 0.01$) and that between the C1 and the C2 not significant. Thus significant differences in treatment x genotype interaction between the C1 and the C2 with regard to wheat straw intake could only be associated with High-Low feeding and not with Low-High feeding.

Table 11: Effects of genotype and feeding level on post-weaning growth, energy and feed intake, means \pm se

Trait	N	Week						1 – 6	Week						7 – 12	Total	
		1	2	3	4	5	6		7	8	9	10	11	12			
		Live weight, kg						ADG, g	Live weight, kg						ADG, g	ADG Total g	
Treatment 1 (High-Low)	15	16.9 ^a \pm 1.19	17.9 ^a \pm 1.27	18.7 ^a \pm 1.39	19.7 ^a \pm 1.39	20.3 ^a \pm 1.45	21.2 ^a \pm 1.46	114.6 ^a \pm 14.37	20.8 ^a \pm 1.37	21.4 ^a \pm 1.38	22.1 ^a \pm 1.36	22.5 ^a \pm 1.38	23.5 ^a \pm 1.46	24.1 ^a \pm 1.33	68.6 ^a \pm 5.77	91.6 ^a \pm 6.89	
Treatment 2 (Low-High)	15	16.6 ^b \pm 1.18	17.2 ^b \pm 1.25	17.5 ^b \pm 1.24	18.1 ^b \pm 1.27	18.9 ^b \pm 1.26	19.7 ^b \pm 1.33	93.8 ^b \pm 5.77	21.0 ^b \pm 1.40	22.0 ^b \pm 1.4a	22.8 ^b \pm 1.38	24.0 ^b \pm 1.49	24.80 ^b \pm 1.47	26.51 ^b \pm 1.55	162.4 ^b \pm 9.81	128.1 ^b \pm 7.06	
Genotype																	
roon	Came	10	12.3 ^a \pm 0.64	12.8 ^a \pm 0.66	13.0 ^a \pm 0.61	13.6 ^a \pm 0.75	14.0 ^a \pm 0.76	14.9 ^a \pm 0.79	72.9 ^a \pm 17.57	15.3 ^a \pm 0.83	16.1 ^a \pm 0.80	16.8 ^a \pm 0.79	17.2 ^a \pm 0.78	17.9 ^a \pm 0.81	19.3 ^a \pm 0.90	106.0 ^a \pm 11.83	89.4 ^a \pm 10.73
	C1	10	17.4 ^b \pm 1.39	18.2 ^b \pm 1.52	19.0 ^b \pm 1.50	20.0 ^b \pm 1.52	20.7 ^b \pm 1.52	21.5 ^b \pm 1.52	116.7 ^b \pm 17.36	22.0 ^b \pm 1.47	22.9 ^b \pm 1.54	23.7 ^b \pm 1.42	24.6 ^b \pm 1.48	25.7 ^b \pm 1.50	27.0 ^b \pm 1.67	130.7 ^b \pm 18.8	123.7 ^b \pm 8.80
	C2	10	20.6 ^c \pm 0.53	21.7 ^c \pm 0.52	22.5 ^c \pm 0.70	23.1 ^b \pm 0.67	24.1 ^c \pm 0.67	25.0 ^c \pm 0.72	123.1 ^b \pm 8.14	25.4 ^c \pm 0.52	26.1 ^c \pm 0.48	26.8 ^c \pm 0.53	28.0 ^c \pm 0.49	28.8 ^c \pm 0.54	29.6 ^b \pm 0.55	109.8 ^a \pm 22.44	116.4 ^b \pm 8.55
		Total energy intake/day, MJ ME															
Treatment 1 (High-Low)	15	4.09 ^a \pm 0.26	5.58 ^a \pm 0.33	6.55 ^a \pm 0.48	7.58 ^a \pm 0.59	8.60 ^a \pm 0.62	9.34 ^a \pm 0.69	6.96 ^a \pm 0.45	6.53 ^a \pm 0.34	6.55 ^a \pm 0.30	6.66 ^a \pm 0.29	6.67 ^a \pm 0.36	6.97 ^a \pm 0.30	7.06 ^a \pm 0.31	6.74 ^a \pm 0.31	6.85 ^a \pm 0.36	
Treatment 2 (Low-High)	14	4.48 ^a \pm 0.11	5.64 ^a \pm 0.27	5.80 ^a \pm 0.33	6.17 ^b \pm 0.29	6.29 ^b \pm 0.31	6.79 ^b \pm 0.38	5.86 ^b \pm 0.26	7.27 ^a \pm 0.38	8.70 ^b \pm 0.43	8.87 ^b \pm 0.44	9.40 ^b \pm 0.54	10.20 ^b \pm 0.60	10.85 ^b \pm 0.68	9.21 ^b \pm 0.47	7.54 ^a \pm 0.35	
Genotype																	
roon	Came	9	3.87 ^a \pm 0.27	4.89 ^a \pm 0.34	5.25 ^a \pm 0.61	5.76 ^a \pm 0.75	6.02 ^a \pm 0.83	6.10 ^a \pm 0.66	5.32 ^a \pm 0.56	5.75 ^a \pm 0.34	6.31 ^a \pm 0.46	6.42 ^a \pm 0.45	6.12 ^a \pm 0.47	6.55 ^a \pm 0.42	6.73 ^a \pm 0.54	6.31 ^a \pm 0.41	5.81 ^a \pm 0.35
	C1	10	4.19 ^{ab} \pm 0.32	5.44 ^{ab} \pm 0.44	6.21 ^{ab} \pm 0.44	7.02 ^{ab} \pm 0.54	7.55 ^b \pm 0.45	8.72 ^b \pm 0.61	6.52 ^b \pm 0.36	6.83 ^b \pm 0.48	7.66 ^b \pm 0.56	7.85 ^b \pm 0.54	8.33 ^b \pm 0.60	9.00 ^b \pm 0.67	9.35 ^b \pm 0.80	8.17 ^b \pm 0.56	7.35 ^b \pm 0.37
	C2	10	4.73 ^b \pm 0.03	6.43 ^b \pm 0.03	7.00 ^b \pm 0.38	7.79 ^b \pm 0.44	8.74 ^b \pm 0.60	9.31 ^b \pm 0.78	7.33 ^b \pm 0.33	7.96 ^c \pm 0.16	8.65 ^c \pm 0.42	8.78 ^c \pm 0.48	9.33 ^c \pm 0.63	9.85 ^b \pm 0.75	10.36 ^c \pm 0.86	9.16 ^c \pm 0.52	8.24 ^c \pm 0.18
		Energy intake/day above Maintenance, Factor															
Treatment 1 (High-Low)	15	1.11 ^a \pm 0.07	1.44 ^a \pm 0.07	1.63 ^a \pm 0.10	1.81 ^a \pm 0.13	2.00 ^a \pm 0.12	2.08 ^a \pm 0.10	1.68 ^a \pm 0.08	1.50 ^a \pm 0.02	1.47 ^a \pm 0.01	1.46 ^a \pm 0.01	1.44 ^a \pm 0.04	1.47 ^a \pm 0.02	1.45 ^a \pm 0.01	1.46 ^a \pm 0.01	1.57 ^a \pm 0.04	
Treatment 2 (Low-High)	14	1.23 ^a \pm 0.05	1.48 ^a \pm 0.02	1.50 ^a \pm 0.04	1.56 ^a \pm 0.01	1.54 ^b \pm 0.01	1.62 ^b \pm 0.08	1.49 ^a \pm 0.02	1.66 ^b \pm 0.07	1.91 ^b \pm 0.06	1.89 ^b \pm 0.07	1.91 ^b \pm 0.06	2.02 ^b \pm 0.06	2.04 ^b \pm 0.06	1.91 ^b \pm 0.04	1.70 ^b \pm 0.03	
Genotype																	
roon	Came	9	1.33 ^a \pm 0.10	1.60 ^a \pm 0.08	1.69 ^a \pm 0.16	1.77 ^a \pm 0.19a	1.80 ^a \pm 0.21	1.76 ^a \pm 0.14	1.66 ^a \pm 0.14	1.66 ^a \pm 0.08	1.77 ^a \pm 0.12	1.74 ^a \pm 0.12	1.63 ^a \pm 0.12	1.69 ^a \pm 0.08	1.64 ^a \pm 0.10	1.69 ^a \pm 0.09	1.67 ^a \pm 0.07
	C1	10	1.10 ^b \pm 0.06	1.37 ^b \pm 0.05	1.53 ^a \pm 0.05	1.66 ^a \pm 0.09	1.75 ^a \pm 0.09	1.97 ^a \pm 0.13	1.56 ^a \pm 0.04	1.50 ^a \pm 0.08	1.63 ^b \pm 0.07	1.63 ^a \pm 0.08	1.68 ^a \pm 0.09	1.76 ^a \pm 0.11	1.75 ^a \pm 0.10	1.66 ^a \pm 0.08	1.61 ^a \pm 0.04
	C2	10	1.09 ^b \pm 0.02	1.43 ^b \pm 0.02	1.51 ^a \pm 0.06	1.64 ^a \pm 0.07	1.77 ^a \pm 0.09	1.84 ^a \pm 0.13	1.55 ^a \pm 0.05	1.57 ^a \pm 0.03	1.67 ^a \pm 0.08	1.65 ^a \pm 0.08	1.70 ^a \pm 0.10	1.76 ^a \pm 0.13	1.80 ^b \pm 0.13	1.69 ^a \pm 0.09	1.62 ^a \pm 0.03

Continuation: Table 11: Effects of genotype and feeding level on post-weaning growth, energy and feed intake, means \pm se

Trait	N	Week	2	3	4	5	6	1 – 6	7	8	9	10	11	12	7 – 12	Total	
		1															
		Total DM intake/day, g															
Treatment 1 (High-Low)	15	432.96a \pm 28.17	554.83a \pm 33.09	632.24a \pm 44.41	719.05a \pm 53.43	804.96a \pm 57.75	867.48a \pm 62.62	668.59a \pm 43.20	647.90a \pm 32.19	655.73a \pm 27.02	670.27a \pm 24.30	670.65a \pm 31.01	695.22a \pm 25.46	700.92a \pm 27.65	673.45a \pm 27.09	671.02a \pm 33.97	
Treatment 2 (Low-High)	14	466.90a \pm 14.38	569.10a \pm 27.21	584.54a \pm 31.02	625.68a \pm 25.83	634.21b \pm 27.56	679.31b \pm 33.19	593.29a \pm 24.20	717.92b \pm 33.00	825.84b \pm 40.01	833.25b \pm 40.66	877.19b \pm 48.08	943.65b \pm 52.06	1000.18b \pm 57.77	866.34b \pm 41.77	729.82a \pm 31.61	
Genotype																	
oon	Camer	9	394.57a \pm 28.39	478.13a \pm 30.23	509.44a \pm 53.76	558.14a \pm 62.88	575.94a \pm 70.68	589.52a \pm 54.23	517.62a \pm 48.80	573.63a \pm 34.08	616.87a \pm 38.04	627.59a \pm 31.79	601.84a \pm 34.78	638.86a \pm 30.84	655.75a \pm 42.08	619.09a \pm 31.63	568.36a \pm 32.32
	C1	10	442.96ab \pm 32.55	548.33a \pm 41.69	612.20a \pm 39.65	688.63a \pm 44.48	732.30b \pm 36.13	834.43b \pm 50.79	643.14b \pm 32.69	682.20b \pm 40.86	749.69b \pm 48.30	766.59b \pm 45.39	805.89b \pm 49.24	863.36b \pm 56.06	893.00b \pm 66.13	793.45b \pm 47.37	718.30b \pm 33.39
	C2	10	505.03b \pm 3.13	650.34b \pm 2.86	696.01b \pm 31.82	763.57b \pm 36.25	844.70b \pm 50.45	887.24b \pm 63.75	724.48b \pm 27.38	778.47c \pm 14.43	834.90c \pm 35.38	840.54c \pm 39.38	886.50c \pm 49.79	925.61b \pm 57.73	968.47b \pm 66.45	872.42c \pm 41.12	798.45c \pm 13.90
		Concentrates, DM/day, g															
Treatment 1 (High-Low)	15	281.59a \pm 18.44	409.52a \pm 25.13	494.88a \pm 37.64	518.25a \pm 47.72	668.35a \pm 48.11	730.49a \pm 55.21	527.68a \pm 34.77	480.41a \pm 26.03	476.95a \pm 24.04	482.87a \pm 24.14	484.39a \pm 30.00	509.93a \pm 24.66	518.32a \pm 25.48	492.15a \pm 25.09	509.91a \pm 28.56	
Treatment 2 (Low-High)	14	312.16a \pm 5.97	403.17a \pm 19.49	414.47a \pm 24.34	437.25b \pm 23.32	448.77b \pm 23.91	487.48b \pm 30.55	417.22b \pm 19.30	532.15a \pm 29.95	661.58b \pm 31.71	682.19b \pm 33.41	731.05b \pm 41.01	797.67b \pm 48.38	855.25b \pm 53.82	709.98b \pm 35.51	563.60b \pm 25.79	
Genotype																	
oon	Camer	9	280.09a \pm 17.47	361.56a \pm 25.08	389.77a \pm 45.69	425.33a \pm 57.88	448.79a \pm 64.21	451.74a \pm 51.87	392.88a \pm 42.57	424.53a \pm 22.72	482.83a \pm 38.35	493.81a \pm 41.45	479.87a \pm 47.00	515.40a \pm 44.40	541.43a \pm 56.97	489.65a \pm 38.32	441.26a \pm 26.08
	C1	10	288.61a \pm 22.94	394.11a \pm 33.56	459.93a \pm 35.68	522.70ab \pm 47.08	567.67b \pm 40.18	663.86b \pm 52.68	482.81b \pm 29.45	499.84b \pm 39.97	571.21b \pm 46.80	586.14b \pm 45.79	627.74b \pm 51.14	683.43b \pm 57.36	713.63b \pm 67.92	613.67b \pm 47.99	548.24b \pm 30.33
	C2	10	321.93a \pm 2.31	463.37b \pm 2.71	514.31b \pm 31.62	579.71b \pm 37.26	659.23b \pm 50.42	711.36b \pm 67.08	541.65b \pm 27.90	594.47c \pm 13.11	653.76 \pm 35.36	667.63c \pm 42.18	715.54c \pm 55.83	762.57c \pm 67.35	805.30c \pm 76.73	699.88c \pm 45.96	620.77c \pm 15.57
		Straw intake, DM/day, g															
Treatment 1 (High-Low)	15	151.37a \pm 11.55	145.30a \pm 11.97	137.36a \pm 12.51	137.80a \pm 12.58	136.61a \pm 13.04	136.98a \pm 9.50	140.90a \pm 11.28	167.50a \pm 7.48	178.78a \pm 5.07	187.40a \pm 0.31	186.26a \pm 1.46	185.29a \pm 2.24	182.60a \pm 3.83	181.30a \pm 2.67	161.10a \pm 6.63	
Treatment 2 (Low-High)	14	153.99a \pm 9.28	160.86a \pm 7.72	164.82b \pm 8.26	182.34b \pm 2.47	179.33b \pm 4.00	183.94b \pm 2.66	170.88b \pm 4.86	180.92b \pm 3.44	158.92b \pm 9.49	146.74b \pm 10.67	145.03b \pm 10.51	142.67b \pm 11.10	146.50b \pm 9.97	153.46b \pm 7.64	162.17a \pm 5.71	
Genotype																	
oon	Camer	9	116.89a \pm 10.62	113.30a \pm 10.23	114.24a \pm 13.07	124.65a \pm 18.16	117.63a \pm 16.58	129.48a \pm 15.13	119.37a \pm 12.04	153.52a \pm 10.65	145.60a \pm 13.35	147.98a \pm 16.56	148.14a \pm 15.97	149.67a \pm 15.03	151.62a \pm 11.85	149.42a \pm 10.21	134.39a \pm 4.65
	C1	10	154.34b \pm 12.39	154.21b \pm 10.22	152.27b \pm 13.28	165.93b \pm 9.00	164.63b \pm 10.12	170.57b \pm 7.71	160.33b \pm 9.02	182.36b \pm 2.66	178.47b \pm 6.57	180.44b \pm 5.39	178.14b \pm 6.42	179.93b \pm 5.24	179.37b \pm 5.97	179.79b \pm 4.65	170.06b \pm 5.49
	C2	10	183.10b \pm 3.28	186.97c \pm 0.38	181.70c \pm 3.26	183.86b \pm 2.13	185.47b \pm 1.57	175.89b \pm 5.13	182.83c \pm 1.82	184.00b \pm 3.21	181.14b \pm 2.70	172.91b \pm 7.41	170.96a \pm 8.30	163.04a \pm 12.26	163.17a \pm 12.28	172.54b \pm 6.31	177.68b \pm 3.20

Different letters within columns indicate significant differences $p \leq 0.05$

The effect of treatment on the intake of wheat straw was not significant over the whole experimental period. The effect of genotype was highly significant but that of sex was not significant over the same period. During 1 - 6 weeks, the effect of treatment on the intake of wheat straw was very significant, that of genotype was highly significant whereas that of sex was not. During 7 - 12 weeks, the effect of treatment on the intake of wheat straw was highly significant, that of genotype was very significant whereas that of sex was not.

Lambs in the High-Low treatment ($161.10 \pm 6.63 \text{g/d}$) consumed almost the same amount of wheat straw per lamb and per day as those in the Low-High treatment ($162.17 \pm 5.71 \text{g/d}$) over the whole experimental period. During 1 - 6 weeks, lambs in the High-Low treatment ($140.90 \pm 11.28 \text{g/d}$) consumed less than those in the Low-High treatment ($170.88 \pm 4.86 \text{g/d}$) and the difference between the treatments was significant. During 7 - 12 weeks, lambs in the High-Low treatment ($181.30 \pm 2.67 \text{g/d}$) consumed significantly more wheat straw than those in the Low-High treatment ($153.46 \pm 7.64 \text{g/d}$). Thus, irrespective of treatment, the Low phase of feeding with concentrated feed was associated with increase in consumption of wheat straw. The C1 ($170.06 \pm 5.49 \text{g/d}$) and C2 ($177.68 \pm 3.20 \text{g/d}$) crosses consumed significantly more wheat straw than the Cameroon ($134.39 \pm 4.65 \text{g/d}$) over the whole experimental period. The difference between the C1 and the C2 crosses was not significant. During 1 - 6 weeks, the C2 crosses ($182.83 \pm 1.82 \text{g/d}$) consumed significantly more wheat straw than the C1 crosses ($160.33 \pm 9.02 \text{g/d}$) and the Cameroon ($119.37 \pm 12.04 \text{g/d}$); the difference between the C1 crosses and the Cameroon was also significant. During 7 - 12 weeks, the C1 ($179.79 \pm 4.65 \text{g/d}$) and C2 ($172.54 \pm 6.31 \text{g/d}$) consumed significantly more wheat straw than the Cameroon ($149.42 \pm 10.21 \text{g/d}$). The difference between the C1 and the C2 crosses was not significant.

In all, the Low-High feeding treatment was associated with a significant increase in ADG compared with the High-Low treatment. Significant increase in ADG was associated with significant increase in energy intake during the High feeding phase (7 - 12 weeks). The C1 and C2 crossbred lambs achieved significantly higher ADG than the Cameroon. Between the C1 and the C2, the latter achieved higher but not significantly different ADG during the first six (1 - 6) weeks of the experiment. During the second six (7 - 12) weeks of the experiment, the C1 achieved significantly higher ADG than the C2. In either treatment, each Low feeding phase was associated with significant increase in wheat straw intake. The Cameroon and the crossbred lambs differed much with regard to their intake of wheat straw. Differences between the C1 and the C2 with regard to the same occurred during the first six (1 - 6) weeks of the experiment.

Table 12 shows the means and standard errors of end live body weight, growth and feed consumption pattern of Cameroon, C1 (Cameroon X Mutton) and C2 (Cameroon X Milk) crossbred lambs of both the High-Low and Low-High treatment groups. The Cameroon and C1 and C2 crossbred lambs in the Low-High treatment group achieved heavier end weight than those of the same genotype subjected to the High-Low treatment. This is explained by the fact that lambs in the Low-High treatment group achieved higher growth rates than those of the same genotype in the High-Low treatment group. The difference in the ADG of the C2 crosses in the Low-High treatment group was significantly higher than that of the C2 crosses in the High-Low one due to the fact that the latter suffered drastic loss of weight during the first week (7) of change-over to the Low feeding phase. Cameroon and C1 and C2 crossbred lambs in the Low-High treatment group consumed more energy above maintenance level than those of the same genotype in the High-Low treatment group although the differences between them was not significant. In both treatment groups, the trend for the Cameroon to consume the highest amount of energy above maintenance, followed by the C2 and then the C1 crossbred lambs, has been noted.

Table 12: Means and standard errors of live body weight, growth and feed intake of lambs of different genotypes in response to different feeding levels

Trait	Feeding level					
	High-Low			Low-High		
	Genotype, n = 5					
	Cameroon	C1	C2	Cameroon	C1	C2
Mean ± se	mean ± se	mean ± se	mean ± se	mean ± se	mean ± se	
End weight, kg	18.7a ±1.26	25.0b ±2.02	28.6b ±0.68	20.0a ±1.36	29.0b ±2.52	30.6b ±0.66
ADG, g	74.5a ±18.22	105.5ab ±5.90	94.7a ±2.91	104.3ab ±8.70	141.9b ±12.14	138.1b ±9.26
MJ ME/W ^{0.75} /d	0.73a ±0.06	0.70a ±0.01	0.70a ±0.01	0.79a ±0.02	0.75a ±0.03	0.76a ±0.02
Energy M, Factor	1.61a ±0.13	1.55a ±0.03	1.56a ±0.03	1.75a ±0.04	1.67a ±0.06	1.68a ±0.05
DM intake/d, g	555.5a ±56.93	677.1ab ±47.48	780.5b ±16.62	584.5a ±21.82	759.5b ±43.75	816.4b ±20.79
Conc. Feed/d, g	422.5a ±49.07	509.6ab ±43.47	597.7bc ±15.77	460.1a ±26.66	586.9bc ±38.78	643.8c ±24.00
Straw/d, g	133.0a ±8.33	167.5b ±7.80	182.8b ±2.34	136.1a ±3.54	172.6b ±8.46	172.5b ±5.24

Different letters within rows indicate significant differences $p \leq 0.05$

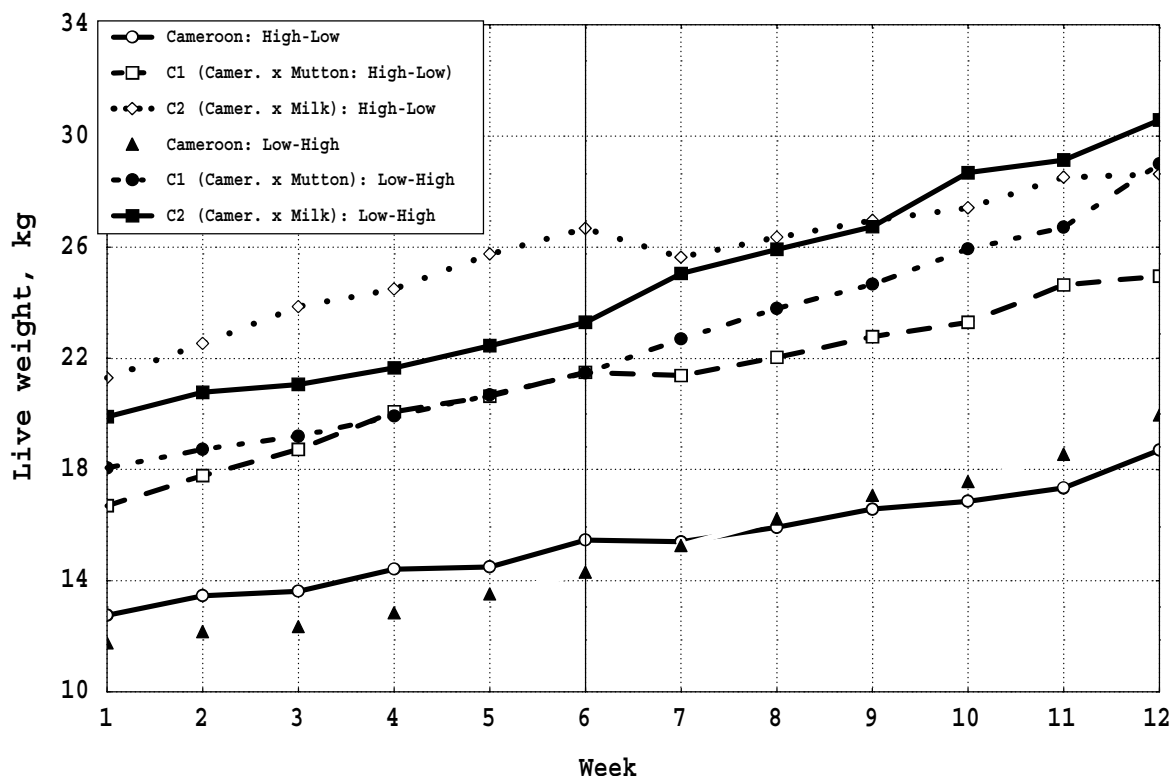


Fig. 2: Post-weaning live body weight of lambs: Reaction to different feeding levels

Except in the case of the C2 crossbred lambs, lambs in the Low-High treatment group consumed a higher amount of wheat straw than those of the same genotype in the Low-High treatment group although the differences between them were not significant ($p > 0.05$).

Fig.2 shows the live body weight per week of the Cameroon and of the C1 and C2 crossbred lambs subjected to the High-Low and Low-High treatments. Despite having lower live body weight (except in the case of the C2) at the beginning of the experiment, lambs in the Low-High treatment group achieved heavier end weight than those of the same genotype in the High-Low treatment group. The comparatively lower live weight of lambs of the Low-High treatment group at the beginning of the experiment may be explained by the higher (9) number of females compared to the High-Low treatment group which had 7. The proportionate break down of the number of female lambs in the High-Low and Low-High treatment groups was 2: 2 for the Cameroon, 2: 3 for the C1 and 3: 4 for the C2 crossbred lambs.

Lambs of the same genotype but belonging to different treatment groups (High-Low or Low-High) showed differences in weight reached during Week 6 i. e. before change-over. There were considerable differences in weight between the Cameroon lambs of both treatment groups. There was, however, no obvious difference in weight of the C1 crossbred lambs of both groups during week 6 but a big one in the case of the C2. The difference in weight among the C1 belonging to both treatment groups was, however, very big during Week 12. Since weight differences between groups were determined more by the Low-High feeding phase than the High-Low, the C1 are hereby identified as the most favoured genotype with regard to Low-High feeding.

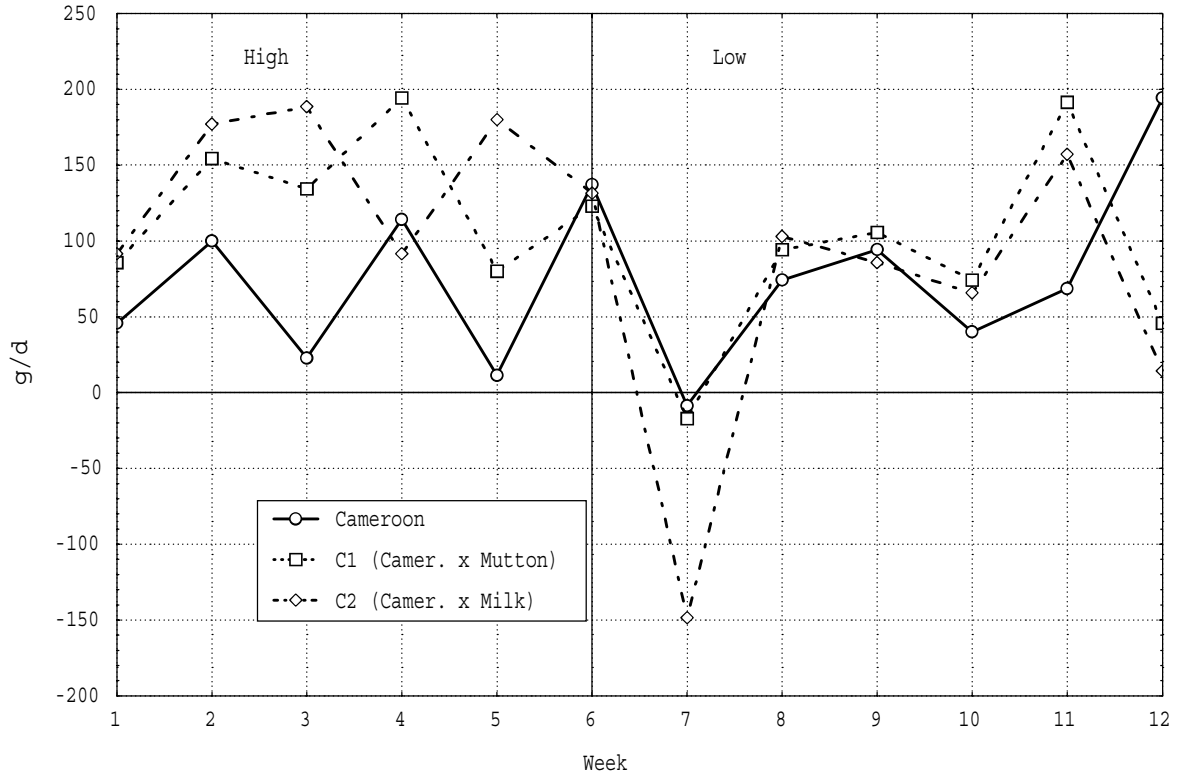


Fig. 3: Average Daily Gain in response to High-Low feeding

Fig. 3 shows the ADG per week of the Cameroon lambs and of the C1 and C2 crosses subjected to the High-Low treatment. During the first six (6) weeks of the High phase of feeding, ADG from one week to the other exhibited an up- and downswing trend that did not conform to any predictable pattern of reaction of the genotypes involved. Only after the administration of the Low phase of feeding (Week 7 to Week 12) did the lambs show any predictable pattern with all lambs first being forced into the downswing to the extent that the Cameroon and C1 crosses recorded zero ADG and the C2 crosses suffered drastic loss of about -150g.

Fig. 4 shows the ADG per week of the Cameroon lambs and of the C1 and C2 crosses subjected to the Low-High treatment. It should be noted that lambs in both the High-Low and Low-High treatments were weighed on the same day using the same scale such that different responses between them can only be reasonably attributed to treatment *per se*. High increases in ADG occurred during Weeks 7, 10 and 12. High increases in ADG during this time should have made up much of the compensatory growth associated with the Low-High treatment. Characteristic of ADG is to assume an up-swing at one time that will be followed by a down-swing and vice versa. It appears that compensatory growth was associated more with the up-swing phase of ADG. During the High phase of the Low-High feeding treatment, the upswing tended to dominate and was clearly present during Week 7, Week 10 (except for the Cameroon lambs) and Week 12.

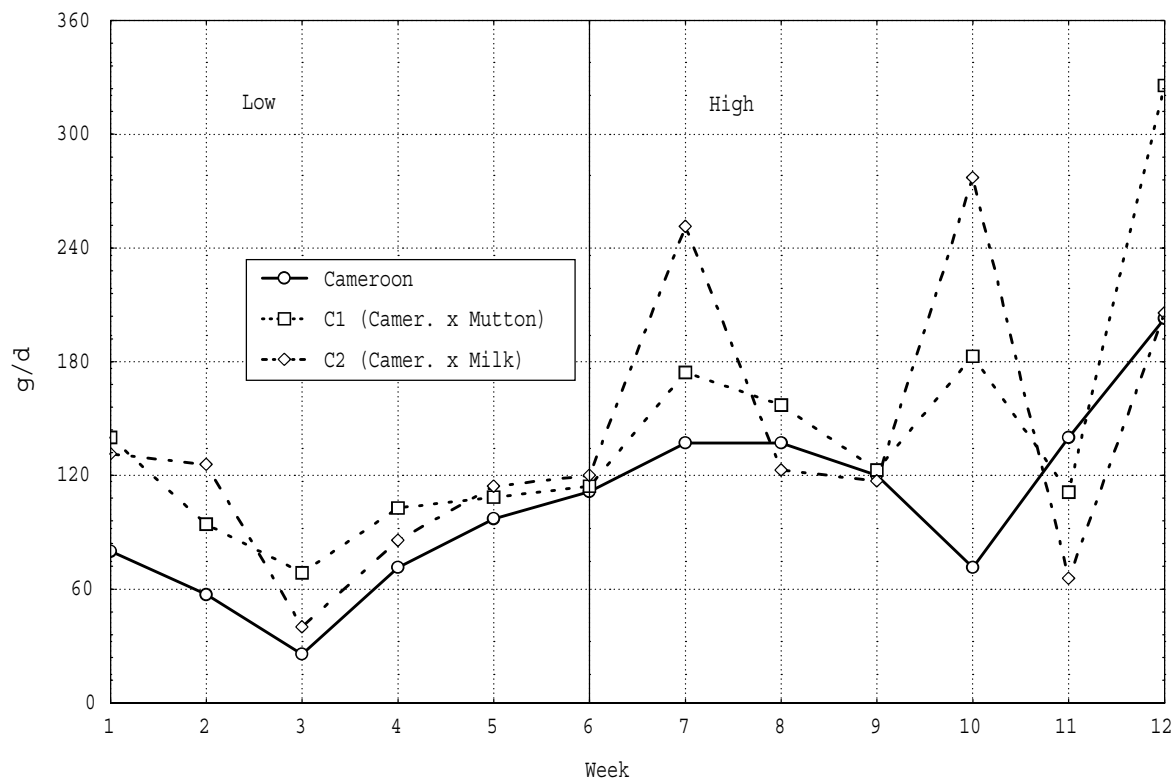


Fig. 4: Average Daily Gain in response to Low-High feeding

Significant increase in ADG of the Low-High treatment during 7 - 12 weeks was always accompanied by significant increase in concentrated feed intake except during Week 7. Significant increase in ADG during Week 7 cannot be associated with any significant increase in concentrated feed intake. Significant increase in concentrated feed intake of the Low-High treatment during Weeks 8 to 12, i. e. over a period of five weeks, was only matched by significant increases in ADG during Weeks 10 and 12. Thus increased feed intake was not associated with increased ADG during three weeks (8, 9 and 11) of the 6-week High phase of feeding. An ideal situation would be to match increase in feed intake with increase in ADG.

From Week 7 to Week 12, it appears that from a lower level, the Cameroon lambs required about two (2) weeks to reach their next higher level of ADG and this conforms with their relatively lower rate of growth.

Fig. 5 shows relative intake of wheat straw per week by the Cameroon lambs and the C1 and C2 crosses subjected to the High-Low feeding treatment. It shows that the Cameroon had a different pattern of consumption than that of the C1 and C2 crossbred lambs during both the High and the Low feeding phases. The Cameroon recorded lower values than both the C1 and C2 crossbred lambs during the High feeding phase but higher values during the Low feeding phase. Between the C1 and C2 crosses, the C1 clearly consumed more than the C2 during the Low feeding phase. Relative intake by the crosses and the Cameroon lambs decreased from about 38% and 28%, respectively, during Week 1 to about 17% at the end of the High feeding phase. It was up again to about 25% and 23% for the C1 and C2 crosses, respectively, during Week 12. That by the Cameroon lambs was then relatively higher at about 30%. In practice, the extent to which the crosses could utilise wheat straw might therefore depend on the degree of availability of supplementation with concentrated feed.

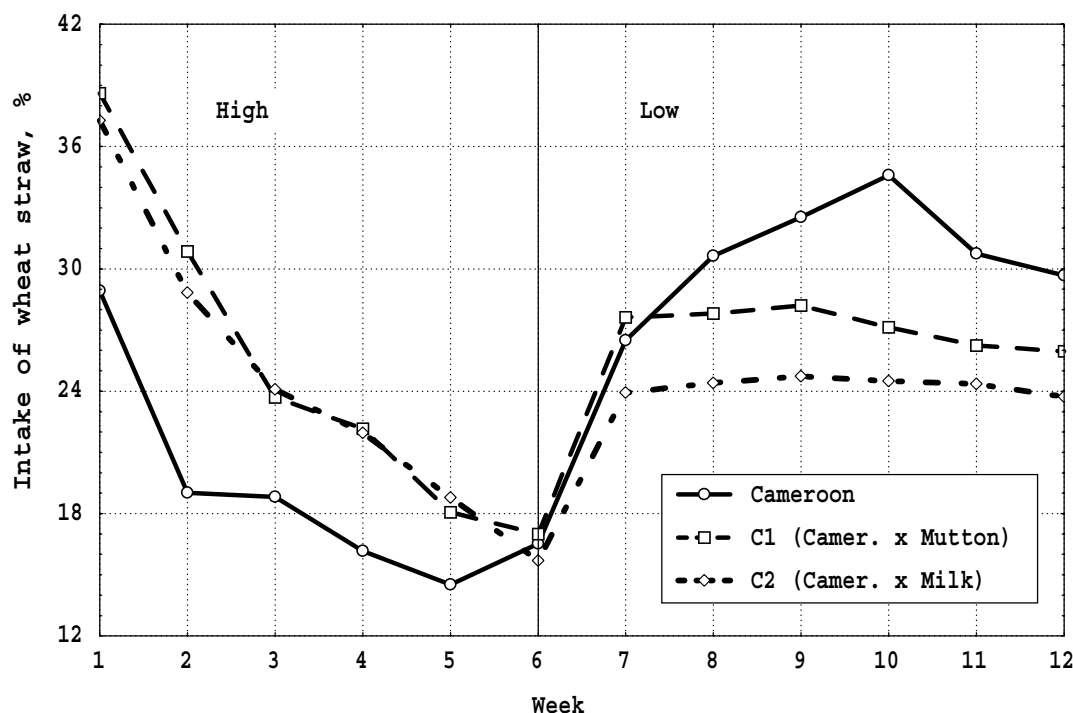


Fig. 5: Mean percentage wheat straw intake of lambs in the High-Low feeding treatment

In general, relative intake of wheat straw reduced with increased intake of concentrated feed and vice versa. Relative intake of wheat straw by the crosses was more stable than that of the Cameroon lambs during the Low feeding phase. During the High feeding phase, there was increased substitution of wheat straw by concentrated feed.

5.3.2 Reaction to high ambient temperature during the day and of alternating feeding levels

The results show the productive performance and physiological reaction of C2 (Cameroon X Mutton) compared with that of the pure Cameroon lambs when subjected to high ($31^{\circ}\text{C}/50\%RH$) ambient temperature during the day and low ($15^{\circ}\text{C}/70\%RH$) at night combined with alternating feeding levels (High-Low-High) administered in the form of *ad libitum* feeding during the first 4 weeks followed by restriction (1.5 times above maintenance) during the next 4 weeks and lastly *ad libitum* feeding during the last 4 weeks. Feeding with wheat straw was fixed at a maximum of 200g per lamb per day.

5.3.2.1 Post-weaning growth performance

The analysis of variance showing the effects of genotype and sex on live body weight, ADG, energy and feed intake of lambs per week, during 1 - 4 weeks, 5 - 8 weeks, 9 - 12 weeks and over the whole experimental period is presented in Table 13. In Table 14 means of live body weight, ADG, energy and feed intake during the same periods have also been presented.

Average Daily Gain: The model explains 0.64 of the variation for ADG over the whole experimental period. During the first four and the second four weeks, the model explains only a small amount of the variation. During 9 - 12 weeks in which realimentation took place, the model explains 0.69 of the variation. During the same period i. e. the overall period, 1 - 4 weeks, 5 - 8 and 9 - 12 weeks, the coefficient of variation was 17.31%, 38.13%, 47.76% and 31.98%, respectively.

The effect of genotype on ADG was not significant over the whole experimental period whereas that of sex was. During 1 - 4 weeks and 5 - 8 weeks, the effect of genotype and sex on ADG was not significant. During 9 - 12 weeks, the effect of genotype and sex on ADG was significant. Over the whole experimental period, the C2 ($120.24 \pm 11.08\text{g/d}$) achieved higher ADG than the pure Cameroon ($98.57 \pm 12.93\text{g/d}$) even if the difference between them was not significant. Following the Low feeding phase (5 - 8 weeks), the C2 crossbred lambs ($167.86 \pm 26.75\text{g/d}$) achieved significantly higher ADG

than the Cameroon ($100.71 \pm 28.38 \text{g/d}$) during the second High feeding phase i. e. during 9 - 12 weeks. Males gained significantly more than females over the whole experimental period and during the second High feeding phase from 9 - 12 weeks.

Intake of energy above maintenance: The model explains 0.50 of the variation for energy intake above maintenance requirement over the whole experimental period. During 1 - 4 weeks, the model explains 0.73 of the variation, 0.32 during 5 - 8 weeks, and 0.45 during 9 - 12 weeks. During the same period i. e. the overall period, 1 - 4 weeks, 5 - 8 and 9 - 12 weeks, the coefficient of variation was 5.90%, 10.29%, 1.40% and 8.47%, respectively.

The effect of intake of energy above maintenance requirement was significantly affected by genotype over the whole experimental period. The effect of sex on intake of energy above maintenance requirement over the same period was not significant. During the first High feeding phase (1 - 4 weeks) the effect of genotype on intake of energy above maintenance requirement was very significant but that of sex was not. During the Low feeding phase (5 - 8 weeks) the Cameroon (1.63 ± 0.03) lambs consumed significantly more energy above maintenance requirement than the C2 crosses (1.48 ± 0.05). During the first High feeding phase (1 - 4 weeks), the Cameroon (1.74 ± 0.06) still consumed significantly more energy above maintenance requirement than the C2 crosses (1.31 ± 0.08). During the Low feeding phase (5 - 8 weeks), the Cameroon consumed 1.49 ± 0.13 times more energy above maintenance requirement compared with 1.58 ± 0.10 for the C2 crosses and as expected and the difference between the genotypes was not significant. During the second High feeding phase (9 - 12 weeks), the Cameroon (1.69 ± 0.06) and the C2 crosses (1.69 ± 0.10) consumed a similar amount of energy above maintenance level. During 9 - 12 weeks, males (1.77 ± 0.03) recorded a significantly higher value than females (1.56 ± 0.10).

Significantly higher ADG achieved by the C2 crossbred lambs during 9 - 12 weeks, compared with the Cameroon, was not due to any difference in intake of energy above maintenance. The C2 crossbred lambs therefore responded better to the Low-High feeding element than did the Cameroon even under conditions of high ambient temperature during the day.

During the second and last High feeding phase (9 - 12 weeks), the effect of genotype and sex on intake of energy above maintenance requirement was not significant. During the second and last High feeding phase (9 - 12 weeks), the effect of genotype on intake of energy above maintenance requirement was not significant but that of sex was.

Table 13: Results of ANOVA of post-weaning live weight, ADG and energy and feed intake of lambs per week

Trait	Week															
	1	2	3	4	1 - 4	5	6	7	8	5 - 8	9	10	11	12	9 - 12	Total
Live weight																
Genotype	***		***	***	N/A	***	***	***	***	N/A	***	***	***	***	N/A	N/A
Sex	*	*	**	**	N/A	**	**	**	**	N/A	**	**	**	**	N/A	N/A
R-SQ	0.87	0.86	0.91	0.89	N/A	0.88	0.90	0.90	0.91	N/A	0.88	0.90	0.90	0.89	N/A	N/A
CV (%)	11.30	11.08	7.97	9.06	N/A	8.71	8.31	8.35	7.50	N/A	8.57	8.71	8.87	9.40	N/A	N/A
Average Daily Gain																
Genotype	Ns	Ns	Ns	Ns	ns	ns	Ns	ns	ns	Ns	ns	ns	ns	ns	*	ns
Sex	Ns	Ns	Ns	Ns	ns	ns	Ns	ns	ns	Ns	ns	ns	ns	ns	*	*
R-SQ	0.00	0.01	0.05	0.13	0.00	0.08	0.12	0.33	0.05	0.13	0.04	0.47	0.34	0.27	0.69	0.64
CV (%)	73.48	121.70	116.86	79.31	38.13	234.30	105.99	54.82	367.15	47.76	58.95	100.74	130.99	70.39	31.98	17.31
Total energy intake, ME MJ																
Genotype	Ns	Ns	Ns	Ns	ns	***	***	***	***	***	**	**	**	ns	**	**
Sex	Ns	ns	Ns	Ns	ns	**	**	**	***	**	**	**	**	ns	**	**
R-SQ	0.03	0.14	0.31	0.46	0.22	0.91	0.90	0.87	0.92	0.90	0.84	0.90	0.86	0.53	0.83	0.81
CV (%)	15.44	21.10	11.61	12.71	13.11	6.54	5.73	6.97	5.03	5.78	7.89	7.73	12.30	25.80	10.88	8.20
Energy intake above M, Factor																
Genotype	**	*	**	**	**	ns	Ns	ns	ns	Ns	ns	ns	ns	ns	ns	*
Sex	*	ns	Ns	Ns	ns	ns	Ns	ns	ns	Ns	ns	*	ns	ns	*	ns
R-SQ	0.76	0.48	0.70	0.69	0.73	0.07	0.07	0.23	0.37	0.32	0.11	0.50	0.54	0.28	0.45	0.50
CV (%)	14.48	15.26	11.79	8.84	10.29	2.39	2.67	3.36	2.01	1.40	6.67	6.51	11.33	23.03	8.47	5.90
Total DM intake																
Genotype	Ns	Ns	Ns	Ns	ns	***	***	***	***	***	**	**	**	ns	**	**
Sex	Ns	Ns	ns	Ns	ns	**	**	**	***	**	**	**	**	*	**	**
R-SQ	0.02	0.24	0.41	0.49	0.33	0.91	0.92	0.87	0.92	0.91	0.86	0.88	0.85	0.50	0.81	0.81
CV (%)	13.43	18.27	9.28	11.26	11.32	5.01	5.26	6.41	4.65	5.07	6.72	7.83	11.64	24.21	10.77	7.65
Concentrates, DM																
Genotype	Ns	Ns	ns	Ns	ns	***	***	***	***	***	**	**	**	ns	**	*
Sex	Ns	Ns	ns	Ns	ns	**	**	*	**	**	*	***	**	*	**	**
R-SQ	0.11	0.07	0.26	0.43	0.16	0.88	0.89	0.85	0.90	0.89	0.81	0.90	0.86	0.55	0.84	0.79
CV (%)	17.93	24.11	14.29	14.38	15.15	7.28	6.48	7.94	6.14	6.82	9.16	8.14	13.25	27.31	11.19	8.95
Straw intake, DM																
Genotype	*	*	ns	Ns	*	ns	*	ns	ns	Ns	ns	ns	ns	ns	ns	ns
Sex	*	*	ns	Ns	ns	ns	*	ns	ns	Ns	*	ns	ns	ns	ns	ns
R-SQ	0.68	0.70	0.45	0.39	0.62	0.57	0.71	0.43	0.31	0.52	0.62	0.25	0.20	0.06	0.22	0.53
CV (%)	11.08	14.71	17.68	17.09	12.88	6.47	8.83	11.48	13.18	9.21	9.60	20.69	21.21	16.20	16.36	10.81

*** $p \leq 0.001$; ** $p \leq 0.01$; * $p \leq 0.05$; ns for not significant

Table 14: Means and standard errors of post-weaning live weight, ADG and energy and feed intake of lambs per week by genotype and sex

Trait	n	Start	Week														9 - 12	Total
			1	2	3	4	1 - 4	5	6	7	8	5 - 8	9	10	11	12		
Live weight, kg																		
Genotype																		
Cameroon	5	12.1a	13.1a	13.7a	14.8a	15.5a	N/A	15.9a±	16.4a±	17.1a±	17.5a±	N/A	18.7a±	19.0a±	19.3a±	20.3a±	N/A	N/A
		±1.43	±1.55	±1.68	±1.35	±1.57		1.49	1.49	1.72	1.47		1.77	1.71	2.01	2.15		
C2	5	19.0b	20.0b	20.8b	21.5b	22.5b	N/A	22.6b	23.2b	24.3b	24.4b	N/A	25.8b	27.4b	28.0b	29.1b	N/A	N/a
		±1.10	±0.82	±0.62	±0.87	±0.74		±0.84	±0.99	±0.87	±1.17		±1.01	±1.52	±1.52	±1.82		
Sex																		
Male	6		18.1a	18.9a	19.8a	20.6a	N/A	20.9a	21.5a	22.6a	22.8a	N/A	24.2a	25.4a	26.2a	27.6a	N/A	N/A
			±1.54	±1.43	±1.47	±1.43		±1.45	±1.50	±1.50	±1.61		±1.59	±2.00	±1.97	±2.10		
Female	4		14.2b	14.8b	15.8b	16.5b	N/A	16.8b	17.2	17.9b	18.2b	N/A	19.3b	19.8b	19.9b	20.5b	N/A	N/A
			±2.46	±2.71	±2.25	±2.62		±2.38	±2.37	±2.67	±2.21		±2.50	±2.67	±2.94	±2.86		
Average Daily Gain, g																		
Genotype																		
Cameroon	5		142.9a	97.1a	160.0a	85.7a	121.4a	65.7a	65.7a	100.0a	62.9a	73.6a	168.6a	40.0a	48.6a	145.7a	100.7a	98.6a
			±22.59	±36.53	±49.16	±46.73	±14.98	±41.06	±21.00	±34.11	±50.63	±5.71	±55.59	±40.76	±47.94	±48.95	±28.38	±12.93
C2	5		137.1a	114.3a	105.7a	137.1a	123.6a	17.1a	82.9a	165.7a	11.4a	69.3a	194.3a	231.4a	88.6a	157.1a	167.9b	120.2a
			±56.53	±66.85	±77.80	±24.99	±23.24	±40.25	±44.58	±32.45	±62.83	±20.84	±31.82	±78.17	±42.23	±54.96	±26.75	±11.08
Sex																		
Male	6		138.1a	109.5a	126.2a	121.4a	123.8a	38.1a	92.9a	154.8a	35.7a	80.4a	192.9a	176.2a	109.5a	195.2a	168.4a	124.2a
			±45.28	±49.85	±38.23	±26.28	±20.34	±37.19	±18.72	±27.95	±43.29	±12.50	±44.53	±84.33	±29.89	±40.35	±21.56	±9.64
Female	4		142.9a	100.0a	142.9a	96.4a	120.5a	46.4a	46.4a	100.0a	39.3a	50.0a	164.3a	75.0a	7.1a	85.7a	83.0b	87.2b
			±32.47	±59.19	±104.98	±58.1	±15.46	±50.30	±52.93	±45.18	±81.94	±17.09	±43.06	±27.59	±52.97	±50.84	±29.21	±8.66
Total energy intake/day, ME MJ																		
Genotype																		
Cameroon	5		4.59a	5.41a	6.33a	6.52a	5.71a	5.27a	5.35a	5.48a	5.76a	5.46a	6.78a	7.31a	6.75a	7.31a	7.04a	6.07a
			±0.13	±0.51	±0.47	±0.57	±0.41	±0.36	±0.34	±0.37	±0.37	±0.36	±0.58	±0.74	±0.89	±0.76	±0.72	±0.49
C2	5		4.42a	5.83a	6.16a	6.91a	5.83a	6.80b	6.93b	7.08b	7.22b	7.01b	8.49b	9.50b	9.99b	8.66a	9.16b	7.33b
			±0.39	±0.53	±0.21	±0.36	±0.30	±0.18	±0.20	±0.21	±0.23	±0.21	±0.25	±0.52	±0.73	±1.53	±0.72	±0.33
Sex																		
Male	6		4.48a	5.89a	6.57a	7.23a	5.71a	6.42a	6.53a	6.67a	6.95a	5.46a	8.24a	9.36a	9.50a	9.37a	7.04a	7.27a
			±0.32	±0.44	±0.29	±0.23	±0.41	±0.31	±0.34	±0.37	±0.31	±0.36	±0.31	±0.46	±0.67	±0.56	±0.72	±0.25
Female	4		5.54a	5.22a	5.76a	5.95a	5.37a	5.45b	5.56b	5.68b	5.81b	5.62b	6.73b	6.98b	6.67b	5.91b	6.57b	5.85b
			±0.16	±0.60	±0.32	±0.57	±0.39	±0.57	±0.56	±0.55	±0.51	±0.55	±0.76	±0.84	±1.30	±1.44	±0.90	±0.59
Energy intake/day above Maintenance, Factor																		
Genotype																		
Cameroon	5		1.53a	1.70a	1.87a	1.86a	1.74a	1.47a	1.47a	1.46a	1.50a	1.47a	1.68a	1.78a	1.61a	1.69±	1.69±	1.63±
			±0.10	±0.06	±0.09	±0.05	±0.06	±0.02	±0.02	±0.03	±0.01	±0.01	±0.07	±0.07	±0.11	0.04a	0.06a	0.03a
C2	5		1.05b	1.34b	1.38b	1.49b	1.31b	1.46a	1.46a	1.44a	1.46a	1.45a	1.65a	1.76a	1.82a	1.51±0.24a	1.69±0.10a	1.48±0.05b
			±0.11	±0.12	±0.07	±0.07	±0.08	±0.01	±0.02	±0.02	±0.01	±0.01	±0.01	±0.06	±0.10			
Sex																		
Male	6		1.18a	1.48a	1.60a	1.69a	1.49a	1.47a	1.46a	1.43a	1.48a	1.46a	1.69a	1.85a	1.83a	1.73a	1.77a	1.57a
			±0.13	±0.15	±0.15	±0.11	±0.13	±0.01	±0.01	±0.01	±0.02	±0.00	±0.03	±0.04	±0.07	±0.03	±0.03	±0.05
Female	4		1.46a	1.57a	1.65a	1.65a	1.58a	1.46a	1.47a	1.47a	1.48a	1.47a	1.63a	1.65b	1.55a	1.40a	1.56b	1.54a
			±0.15	±0.07	±0.12	±0.11	±0.10	±0.02	±0.02	±0.03	±0.02	±0.02	±0.07	±0.06	±0.14	±0.29	±0.10	±0.06

Different letters within columns indicate significant differences $p \leq 0.05$

Continuation: Table 14: Means and standard errors of post-weaning live weight, ADG, energy and feed intake of lambs per week by treatment and by genotype

Trait	Week																	Total
	n	(start)	1	2	3	4	1 - 4	5	6	7	8	5 - 8	9	10	11	12	9 - 12	
Total DM intake/day, g																		
Genotype																		
Cameroon	5		471.4a	528.4a	609.9a	622.2a	558.0a	536.0a	535.3a	552.3a	582.2a	551.5a	663.0a	694.6a	647.5a	705.6a	677.7a	595.7a
			±18.10	±49.45	±40.27	±46.71	±37.62	±31.57	±32.26	±33.61	±32.22	±31.93	±51.64	±62.23	±71.41	±62.40	±60.02	±42.69
C2	5		471.9a	588.5a	615.3a	673.6a	587.3a	674.0b	684.9b	696.9b	706.2b	690.5b	814.1b	895.4b	935.8b	825.0a	867.6b	715.1b
			±33.18	±43.71	±17.34	±34.19	±25.71	±17.96	±20.84	±23.57	±27.12	±22.24	±27.72	±50.66	±69.56	±136.24	±68.83	±33.23
Sex																		
Male	6		477.4a	589.4a	645.1a	692.4a	601.1a	641.4	648.7a	663.4a	688.3a	660.4a	797.2	877.4	888.0a	883.2a	861.4a	707.6a
			±27.35	±36.01	±18.09	±17.60	±19.81	±28.26	±31.77	±34.83	±28.46	±30.57	±29.17	±45.15	±62.26	±51.74	±45.56	±24.45
Female	4		463.1a	512.1a	563.9a	581.1a	530.0a	550.2b	552.3b	566.6b	578.0b	561.8b	650.7b	671.5b	647.1b	588.3b	639.4b	577.1b
			±21.70	±59.88	±32.73	±53.70	±40.62	±50.07	±52.32	±47.51	±41.25	±47.63	±63.76	±74.57	±112.15	±127.69	±79.77	±54.27
Concentrates, DM/day, g																		
Genotype																		
Cameroon	5		326.6a	404.6a	478.7a	497.5a	426.8a	377.5a	389.9a	396.2a	416.6a	395.1a	505.9a	560.6a	513.1a	552.3a	533.0a	451.6a
			±6.86	±39.15	±40.13	±49.48	±32.24	±29.30	±26.57	±30.24	±30.61	±28.96	±47.68	±63.58	±78.06	±65.48	±61.97	±40.42
C2	5		300.2a	421.7a	450.5a	517.5a	422.5a	500.8b	512.1b	524.8b	538.4b	519.0b	645.8b	732.8b	775.5b	662.3a	704.1b	548.5b
			±33.20	±46.44	±18.98	±27.57	±26.02	±14.09	±14.32	±14.65	±15.48	±14.49	±16.32	±39.77	±56.63	±23.87	±55.59	±23.43
Sex																		
Male	6		305.8a	430.1a	488.5a	549.9a	443.6	469.7a	479.6a	490.2a	511.7a	487.8a	621.6a	725.5a	739.2a	722.8a	702.2a	544.5a
			±27.67	±39.20	±29.33	±22.61	±25.85	±24.99	±25.92	±29.18	±25.00	±26.13	±24.61	±34.69	±52.08	±44.24	±37.03	±19.23
Female	4		324.9a	387.7a	428.8a	444.0a	396.3a	393.4b	408.1b	416.0b	426.2b	410.9b	507.3b	528.5b	502.0b	434.1b	493.0b	433.4b
			±8.57	±44.79	±24.19	±43.74	±27.35	±46.92	±43.90	±45.81	±45.02	±45.40	±64.71	±69.18	±108.68	±116.95	±73.94	±46.92
Straw intake, DM/day, g																		
Genotype																		
Cameroon	5		144.9a	123.8a	131.3a	124.7a	131.2a	158.4a	145.4a	156.2a	165.5a	156.4a	157.1a	134.0a	134.3a	153.3a	144.7a	144.1a
			±13.42	±12.35	±13.63	±9.74	±9.86	±3.19	±7.31	±4.78	±3.67	±3.59	±5.72	±10.05	±7.90	±7.88	±6.09	±2.90
C2 (Camer. X Mutton)	5		171.7b	166.8b	164.7a	156.1a	164.8b	173.1a	172.9b	172.1a	167.8a	171.5a	168.3a	162.6a	160.3a	162.7a	163.5a	166.6a
			±7.82	±12.35	±10.45	±10.50	±9.90	±7.53	±9.50	±12.75	±15.15	±11.14	±13.01	±15.42	±16.76	±13.11	±14.32	±11.65
Sex																		
Male	6		171.6a	159.2a	156.6a	142.6a	157.5a	171.7a	169.1a	173.2a	176.6a	172.7a	175.6a	151.9a	148.8a	160.5a	159.2a	163.1a
			±4.96	±11.69	±12.88	±12.74	±9.81	±4.58	±6.87	±6.53	±4.29	±5.09	±4.83	±12.57	±12.19	±8.57	±9.37	±7.19
Female	4		138.2b	124.4b	135.1a	137.1a	133.7a	156.9a	144.2b	150.6a	151.8a	150.8a	143.4b	143.0a	145.0a	154.2a	146.4a	143.7a
			±16.36	±17.60	±14.75	±11.63	±14.41	±7.73	±12.41	±12.39	±15.38	±10.76	±10.50	±18.02	±18.37	±14.73	±14.99	±11.87

Different letters within columns indicate significant differences $p \leq 0.05$

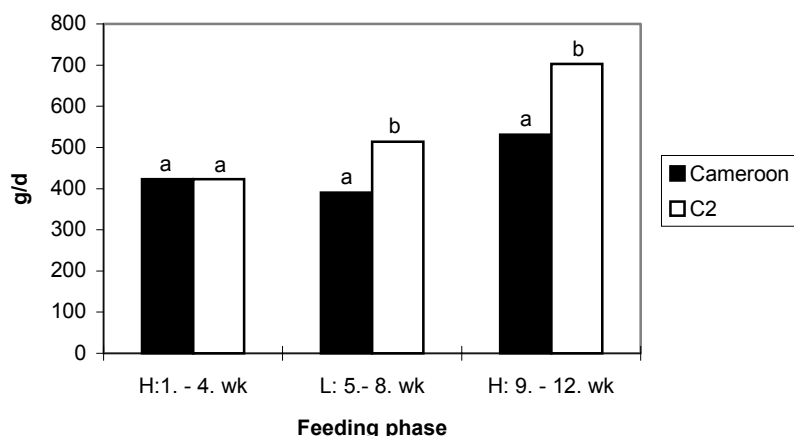


Fig. 6: Mean daily concentrated feed intake of lambs subjected to high ambient temperature and alternating feeding levels

Intake of wheat straw: The Cameroon consumed 144.08 ± 2.90 g/d of wheat straw over the whole experimental period compared with 166.60 ± 11.65 g/d for the C2 crosses. The difference between the Cameroon and the C2 crosses was not significant. During the first High feeding phase from 1 - 4 weeks, the C2 crosses (164.82 ± 9.90 g/d), however, consumed significantly more wheat straw than the Cameroon (131.15 ± 9.86 g/d). The failure of the C2 crossbred lambs to consume all the concentrated feed provided to them during the first four (1 - 4) weeks was compensated for through increased wheat straw intake.

In all, the C2 achieved higher but not significantly different ADG than the Cameroon over the whole experimental period. However, the C2 achieved higher and significantly different ADG than the Cameroon during realimentation in the second High feeding phase (9 - 12 weeks) despite the fact that energy intake above maintenance level was not significantly different between both genotypes.

Fig. 6 shows intake of concentrated feed per day and per week by Cameroon and C2 (Cameroon X Mutton) crossbred lambs during the first High feeding phase, during the Low and the second High feeding phases. The Cameroon and the C2 crosses consumed almost similar amounts of concentrated feed during the first four weeks after which the C2 always consumed more during the Low phase and the second High phase of feeding. The difference between the Cameroon and the C2 crosses was significant during the period, 5 - 11 weeks. Thus at least after the fourth week, the concentrated feed intake of the C2 was no longer disadvantaged compared with that of the Cameroon.

Fig. 7 shows intake of energy above maintenance level per day and per week by Cameroon and C2 (Cameroon X Mutton) crossbred lambs during the first High feeding phase, during the Low and the second High feeding phases. The level of consumption above maintenance was lower in the C2 crosses than in the Cameroon during the first four weeks. This could be associated with the fact that during the first three weeks, the C2 crosses rejected more concentrated feed (3583g) than the Cameroon (2328g). It is also noted that during the same period, the amount of wheat straw rejected by the Cameroon was 2.7 times more than that rejected by the C2 crosses. Level of consumption above maintenance during the second High feeding phase (9 - 12 weeks) was higher for C2 crosses than for the Cameroon during Week 11.

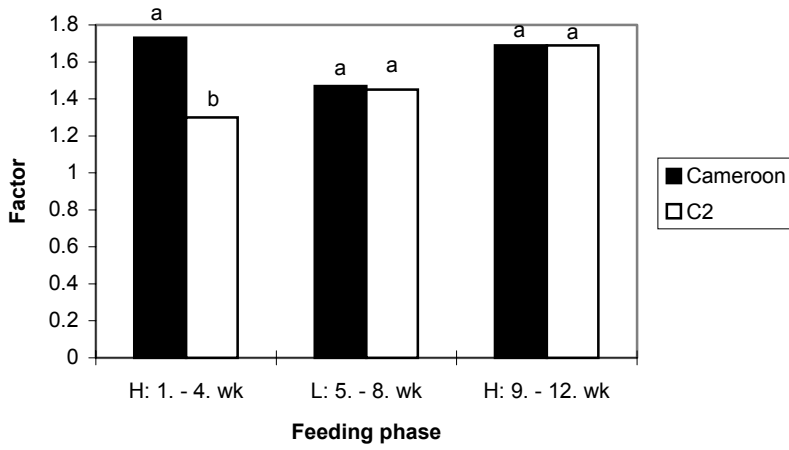


Fig. 7: Intake of energy above maintenance level by lambs subjected to high ambient temperature and alternating feeding levels

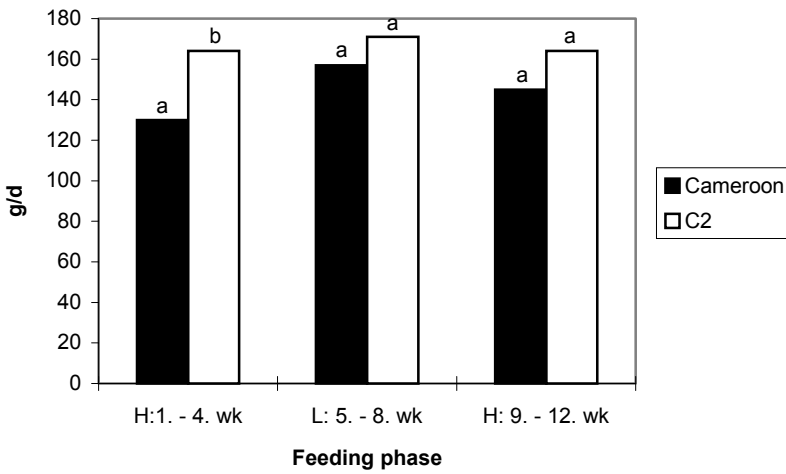


Fig. 8: Mean daily wheat straw intake of lambs subjected to high ambient temperature and alternating feeding levels

Fig. 8 shows absolute intake of wheat straw per day and per week by Cameroon and C2 (Cameroon X Mutton) crossbred lambs during the first High feeding phase, during the Low and the second High feeding phases. Except during Week 4, absolute intake of wheat straw by the C2 crosses was more stable than that by the Cameroon. Intake of the same by the Cameroon though varying much from week to week, tended to be highest during the Low phase of feeding.

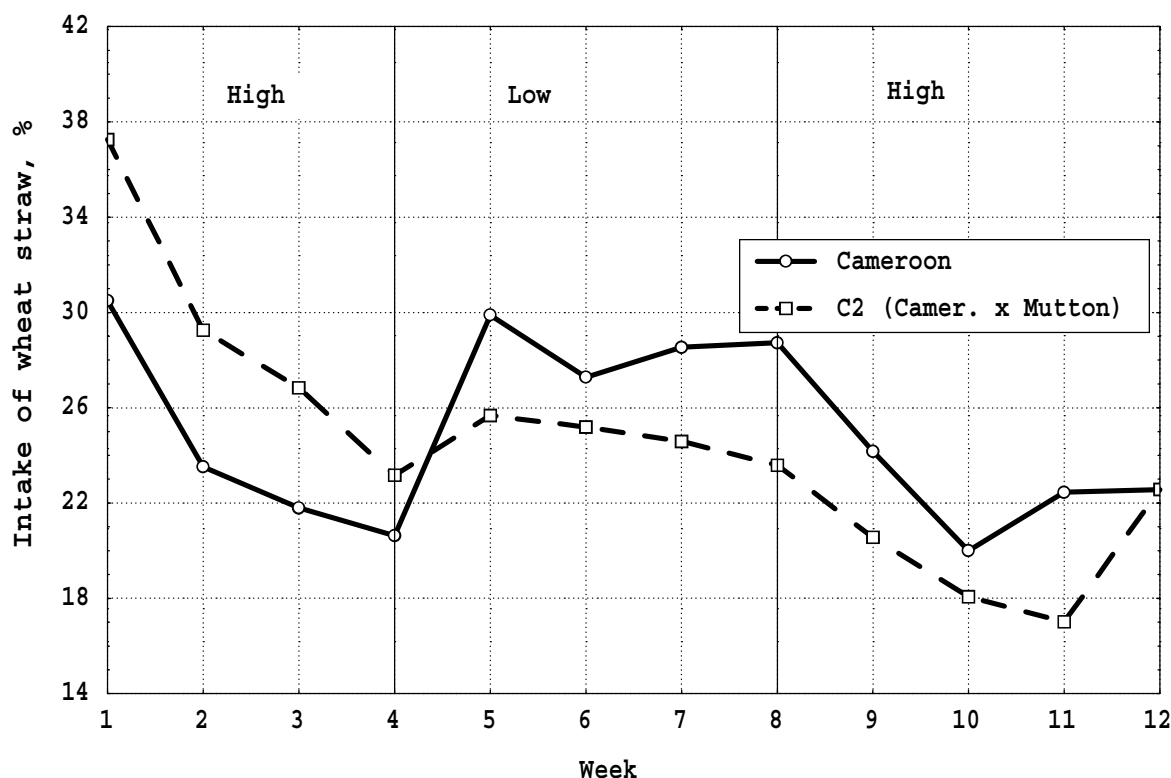


Fig. 9: Mean percentage wheat straw intake of lambs in response at high temperature and alternating feeding levels

Fig. 9 shows relative intake of wheat straw per day and per week by Cameroon and C2 (Cameroon X Mutton) crossbred lambs during the first High feeding phase, during the Low and the second High feeding phases. The Cameroon had a different pattern of consumption than the C2 crossbred lambs during the first High feeding phase and during both the Low and the second High feeding phases. Relative consumption by the Cameroon was lower during the first High feeding phase but higher than that of the C2 (except during Week 12) during both the Low and the second High feeding phases.

Relative intake of wheat straw by both the Cameroon and the C2 crosses reduced during the first High phase of feeding (1 - 4 weeks), then increased slightly during the Low feeding phase (5 - 8 weeks) and was more stable during the second High feeding phase (9 - 12 weeks).

5.3.2.2 Physiological reaction to high ambient temperature

The analysis of variance showing the effects of genotype and sex on rectal temperature and breathing rate of Cameroon lambs and C2 (Cameroon X Mutton) crosses is presented in Table 15. Both rectal temperature and breathing rate were measured at 12⁰⁰ hrs after six (6) hours of exposure to high ambient temperature (31°C/50%RH) and at 20⁰⁰ hrs after two (2) hours change-over to low ambient temperature (15°C/70%RH). It shows the reaction of the lambs over the whole experimental period and during the first High feeding phase (1 - 4 weeks), the Low feeding phase (5 - 8 weeks) and the second High feeding phase (9 - 12 weeks). In Table 16 means of rectal temperature and breathing rate the same periods have also been presented.

Rectal temperature: The model explains 0.78 of the variation for rectal temperature during the day at 12⁰⁰ hrs and at high ambient temperature of 31°C/50%RH over the whole experimental period. During the period of conditioning, 1 - 4 weeks, 5 - 8 weeks and 9 - 12 weeks, the model explains 0.61, 0.33, 0.81, and 0.57 of the variation for this trait. During the same period i. e. the overall period, period of conditioning, 1 - 4 weeks, 5 - 8 and 9 - 12 weeks, the coefficient of variation was 0.22%, 0.28%, 0.37%, 0.30% and 0.35%, respectively.

The effect of genotype on rectal temperature measured at 12⁰⁰ hrs was significant over the whole experimental period but not significant during the period of conditioning and during the first High feeding phase (1 - 4 weeks). The effect of genotype on the same was very significant during the Low feeding phase (5 - 8 weeks) and significant during the second High feeding phase (9 - 12 weeks). The effect of sex on rectal temperature measured at 12⁰⁰ hrs was very significant over the whole period of the experiment. The effect of sex was also significant during the

period of conditioning, not significant during 1 - 4 weeks, very significant during 5 - 8 weeks and not significant during 9 - 12 weeks.

The Cameroon ($39.22 \pm 0.07^{\circ}\text{C}$) recorded lower rectal temperature at 12^{00} hrs over the whole experimental period than the C2 crosses ($39.38 \pm 0.05^{\circ}\text{C}$) which recorded higher. The difference between the Cameroon and the C2 crosses was significant. The significant difference in rectal temperature between the Cameroon and the C2 crosses at 12^{00} hrs over the whole experimental period is explained by significant differences occurring during 5 - 8 weeks and during 9 - 12 weeks (see Table 16). Males ($39.21 \pm 0.04^{\circ}\text{C}$) recorded lower rectal temperature at 12^{00} hrs over the whole experimental period than females ($39.43 \pm 0.08^{\circ}\text{C}$). Females always recorded higher rectal temperature at 12^{00} hrs than males and the difference between them was significant during the period of conditioning, during 5 - 8 weeks and during 9 - 12 weeks (see table 16).

The significant effect of genotype on rectal temperature at 12^{00} hrs and at high ambient temperature of $31^{\circ}\text{C}/50\%\text{RH}$ was thus associated with the Low feeding phase during 5 - 8 weeks and with the second High feeding phase during 9 - 12 weeks. The significant effect of sex on the same trait was associated with the period of conditioning and with the Low feeding phase during 5 - 8 weeks.

The model explains 0.68 of the variation for rectal temperature at 20^{00} hrs at low ambient temperature of $15^{\circ}\text{C}/70\%\text{RH}$ over the whole experimental period. During the period of conditioning, 1 - 4 weeks, 5 - 8 weeks and 9 - 12 weeks, the model explains 0.32, 0.28, 0.79, and 0.52 of the variation for this trait. During the same period i. e. the overall period, period of conditioning, 1 - 4 weeks, 5 - 8 and 9 - 12 weeks, the coefficient of variation was 0.21%, 0.43%, 0.26%, 0.24% and 0.28%, respectively.

The effect of genotype on rectal temperature measured at 20^{00} hrs was not significant over the whole experimental period, during the period of conditioning and during the 1 - 4 weeks. The effect of the same was significant during the Low feeding phase (5 - 8 weeks) but not significant during the second High feeding phase (9 - 12 weeks). The effect of sex on rectal temperature measured at 20^{00} hrs was significant over the whole experimental period but not significant during the period of conditioning and during 1 - 4 weeks. During the Low feeding phase (5 - 8 weeks), the effect of sex on the same trait was very significant but not significant during the High feeding phase (9 - 12 weeks). Rectal temperature measured at 20^{00} hrs amounted to $39.520 \pm 0.06^{\circ}\text{C}$ for the Cameroon over the whole experimental period and to $39.41 \pm 0.04^{\circ}\text{C}$ for the C2 crosses and the difference between them was not significant. The Cameroon always recorded higher rectal temperature at 20^{00} hrs than the C2 crosses but a significant difference between them was only recorded during the Low phase (5 - 8 weeks). Males ($39.40 \pm 0.04^{\circ}\text{C}$) recorded lower rectal temperature over the whole experimental period than the females ($39.56 \pm 0.06^{\circ}\text{C}$) and the difference between them was significant. Females always recorded higher rectal temperature at 20^{00} hrs than males but significant difference between them were only recorded during the whole experimental period already referred to and during the Low feeding phase (5 - 8 weeks).

Table 15: Results of ANOVA for rectal temperature and breathing rate per minute during the high, low and high feeding phases and over the whole experimental period

	Control (start)	High feed (1-4 weeks)	Low feed (5-8 weeks)	High feed (9-12 weeks)	Total (1-12 weeks)
Rectal temperature					
1. Day (12^{00} hrs)					
Genotype	Ns	Ns	**	*	*
Sex	*	Ns	**	ns	**
R-SQ	0.61	0.33	0.81	0.57	0.78
CV (%)	0.28	0.37	0.30	0.35	0.22
2. Night (20^{00} hrs)					
Genotype	Ns	Ns	*	ns	ns
Sex	Ns	Ns	**	ns	*
R-SQ	0.32	0.28	0.79	0.52	0.68

CV (%)	0.43	0.26	0.24	0.28	0.21
Breathing rate					
1. Day (12 ⁰⁰ hrs)					
Genotype	*	Ns	*	*	*
Sex	Ns	Ns	*	*	*
R-SQ	0.56	0.15	0.73	0.72	0.66
CV (%)	17.63	12.72	9.56	12.64	9.25
2. Night (20 ⁰⁰ hrs)					
Genotype	Ns	Ns	ns	ns	ns
Sex	Ns	Ns	ns	ns	ns
R-SQ	0.41	0.38	0.32	0.25	0.27
CV (%)	18.95	20.37	17.94	23.60	19.96

*** $p \leq 0.001$; ** $p \leq 0.01$; * $p \leq 0.05$; ns for not significant; DF Degrees of freedom = 1

The significant effect of genotype and sex on rectal temperature at 20⁰⁰ hrs at low ambient temperature of 15⁰C/70%RH was thus associated with the Low feeding phase during 5 - 8 weeks.

Breathing rate: The model explains 0.66 of the variation for breathing rate during the day at 12⁰⁰ hrs at high ambient temperature of 31⁰C/50%RH over the whole experimental period. During the period of conditioning, 1 - 4 weeks, 5 - 8 weeks and 9 - 12 weeks, the model explains 0.56, 0.15, 0.73, and 0.72 of the variation for this trait. During the same period i. e. the overall period, period of conditioning, 1 - 4 weeks, 5 - 8 and 9 - 12 weeks, the coefficient of variation was 9.25%, 17.63%, 12.72%, 9.56% and 12.64%, respectively.

Table 16: Rectal temperature and breathing rate per minute of lambs during the different feeding level phases at high and low ambient temperature, means \pm se

	N	Control (start)	High feed (1-4 weeks)	Low feed (5-8 weeks)	High feed (9-12 weeks)	Total (1-12 weeks)
Rectal temperature						
1. Day (12 ⁰⁰ hrs)						
Genotype						
Cameroon	5	39.25a \pm 0.08	39.39a \pm 0.09	39.13a \pm 0.07	39.12a \pm 0.08	39.22a \pm 0.07
C2	5	39.37a \pm 0.05	39.43a \pm 0.05	39.39b \pm 0.10	39.33b \pm 0.07	39.38b \pm 0.05
Sex						
Male	6	39.23a \pm 0.05	39.34a \pm 0.05	39.14a \pm 0.05	39.15a \pm 0.07	39.21a \pm 0.04
Female	4	39.43b \pm 0.06	39.51a \pm 0.09	39.44b \pm 0.13	39.32a \pm 0.09	39.43b \pm 0.08
2. Night (20 ⁰⁰ hrs)						
Genotype						
Cameroon	5	39.30a \pm 0.08	39.64a \pm 0.05	39.48a \pm 0.07	39.51a \pm 0.07	39.52a \pm 0.06
C2	5	39.15a \pm 0.07	39.57a \pm 0.04	39.33b \pm 0.08	39.38a \pm 0.04	39.41a \pm 0.04
Sex						
Male	6	39.18a \pm 0.07	39.57a \pm 0.03	39.30a \pm 0.06	39.38a \pm 0.05	39.40a \pm 0.04
Female	4	39.29a \pm 0.10	39.66a \pm 0.07	39.57b \pm 0.05	39.53a \pm 0.06	39.56b \pm 0.06
Breathing rate						
1. Day (12 ⁰⁰ hrs)						
Genotype						
Cameroon	5	39.65a \pm 3.77	77.74a \pm 2.73	66.17a \pm 3.85	66.25a \pm 6.84	67.71a \pm 3.73
C2	5	55.55b \pm 3.23	75.86a \pm 5.60	79.51b \pm 4.95	83.67b \pm 5.32	77.82b \pm 4.44
Sex						
Male	6	47.50a \pm 5.50	74.10a \pm 4.30	67.38a \pm 3.24	67.33a \pm 6.10	67.90a \pm 3.64
Female	4	47.75a \pm 4.25	80.84a \pm 3.19	81.03b \pm 6.25	86.41b \pm 4.75	80.07b \pm 3.83
2. Night (20 ⁰⁰ hrs)						
Genotype						
Cameroon	5	16.15a \pm 1.56	18.13a \pm 1.45	17.44a \pm 1.58	22.86a \pm 2.92	19.31a \pm 1.95
C2	5	13.35a \pm 1.09	14.84a \pm 1.72	16.82a \pm 1.51	24.95a \pm 2.42	18.75a \pm 1.75
Sex						
Male	6	13.67a \pm 1.46	15.28a \pm 1.38	15.73a \pm 1.19	21.83a \pm 2.45	17.48a \pm 1.53
Female	4	16.38a \pm 0.94	18.31a \pm 2.02	19.23a \pm 1.42	27.02a \pm 2.11	21.36a \pm 1.63

Different letters within columns indicate significant differences $p \leq 0.05$

The effect of genotype on breathing rate measured at 12⁰⁰ hrs was significant over the whole experimental period and during the period of conditioning. The effect of genotype on the same was not significant during the first High feeding phase (1 - 4 weeks) but was significant during the subsequent Low (5 - 8 weeks) and High (9 - 12 weeks) phases. The effect of sex on breathing rate measured at 12⁰⁰ hrs was significant over the whole experimental period. The effect of the same was not significant during the period of conditioning and during the first High phase (1 - 4 weeks). The same was again significant during the subsequent Low (5 - 8 weeks) and High (9 - 12 weeks) phases.

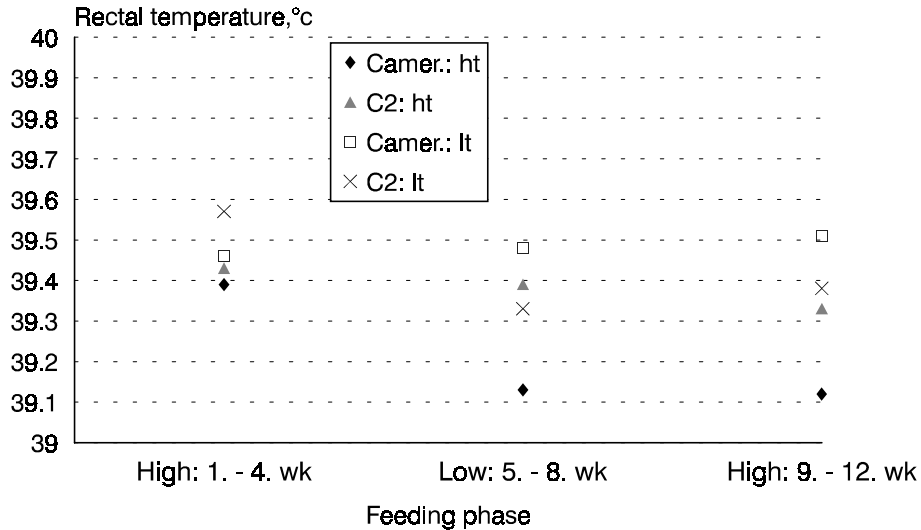


Fig. 10: Effect of fluctuating temperatures (high and low during the day and at night, respectively) on rectal temperature of Cameroon and Cameroon x Mutton lambs during the post-weaning growth phase

The Cameroon (67.71 ± 3.73) recorded significantly lower average breathing rate per minute than the C2 crosses (77.82 ± 4.44) over the whole experimental period. The C2 crosses always recorded significantly higher breathing rate than the Cameroon except during the first High feeding phase (1 - 4 weeks) when the Cameroon recorded a higher value than the C2 crosses even if the difference between them was not significant. This is attributed to the sharp rise in breathing rate of the Cameroon during Week 2. Males (67.90 ± 3.64) recorded lower breathing rate than females (80.07 ± 3.83) over the whole experimental period and the difference between them was significant. Females always recorded higher values than males and significant differences between them over the whole experimental period are explained by significant differences during the Low and the second High phases (see Table 16).

The significant effect of genotype on breathing rate at 12⁰⁰ hrs after six (6) hours of exposure to high ambient temperature ($31^{\circ}\text{C}/50\%\text{RH}$) was thus associated with the period of conditioning, with the Low phase of feeding during 5 - 8 weeks and with the second High feeding phase during 9 - 12 weeks. The significant effect of sex on the same trait was associated with the Low phase during 5 - 8 weeks and with the second High phase during 9 - 12 weeks.

The model explains 0.27 of the variation for breathing rate at 20⁰⁰ hrs after two (2) hours of exposure to low ambient temperature ($15^{\circ}\text{C}/70\%\text{RH}$) over the whole experimental period. During the period of conditioning, 1 - 4 weeks, 5 - 8 weeks and 9 - 12 weeks, the model explains 0.41, 0.38, 0.32, and 0.25 of the variation for this trait. During the same period i. e. the overall period, period of conditioning, 1 - 4 weeks, 5 - 8 and 9 - 12 weeks, the coefficient of variation was 19.96%, 18.95%, 20.37%, 17.94% and 23.60%, respectively. Throughout this period the effect of genotype and sex on breathing rate per minute at 20⁰⁰ hrs was not significant. It amounted to 19.31 ± 1.95 for the Cameroon and 18.75 ± 1.75 for the C2 crosses; 17.48 ± 1.53 for the males and 21.36 ± 1.63 for the females over the whole experimental period.

Fig. 10 shows the rectal temperature of the Cameroon lambs and the C2 (Cameroon X Mutton) crosses measured at 12⁰⁰ hrs during the day at $31^{\circ}\text{C}/50\%\text{RH}$ ambient temperature. Rectal temperature of the Cameroon lambs measured at 12⁰⁰ hrs during the day exhibited a decline from 1 - 4 weeks to 5 - 8 and 9 - 12 weeks. The C2 lambs recorded higher rectal temperature than the Cameroon genotype throughout all three feeding phases. The difference between both genotypes was much wider during 5 - 12 weeks i. e. during the Low phase (5 - 8 weeks) and during the second High phase (9 - 12 weeks). The decline in rectal temperature exhibited by C2 lambs was more gradual compared with the Cameroon.

Fig. 10 also shows the rectal temperature of the Cameroon lambs and the C2 (Cameroon X Mutton) crosses

measured at 20⁰⁰ hrs and at 15°C/70%RH ambient temperature. Rectal temperature at 20⁰⁰ hrs was higher for the Cameroon lambs than for the C2 crosses during every feeding phase. Rectal temperature measured at 20⁰⁰ hrs exhibited a decline from 1- 4 weeks to 5 - 8 weeks after which it showed a slight rise from 5 - 8 weeks to 9 - 12 weeks. The largest difference in rectal temperature between the Cameroon and the C2 crosses was recorded during 5 - 8 weeks when consumption of concentrated feed was restricted to 1.5 times above maintenance level. The C2 crosses recorded lower rectal temperature at 20⁰⁰ hrs than at 12⁰⁰ hrs during 5 - 8 weeks, thus showing a different pattern of reaction influenced by feeding level.

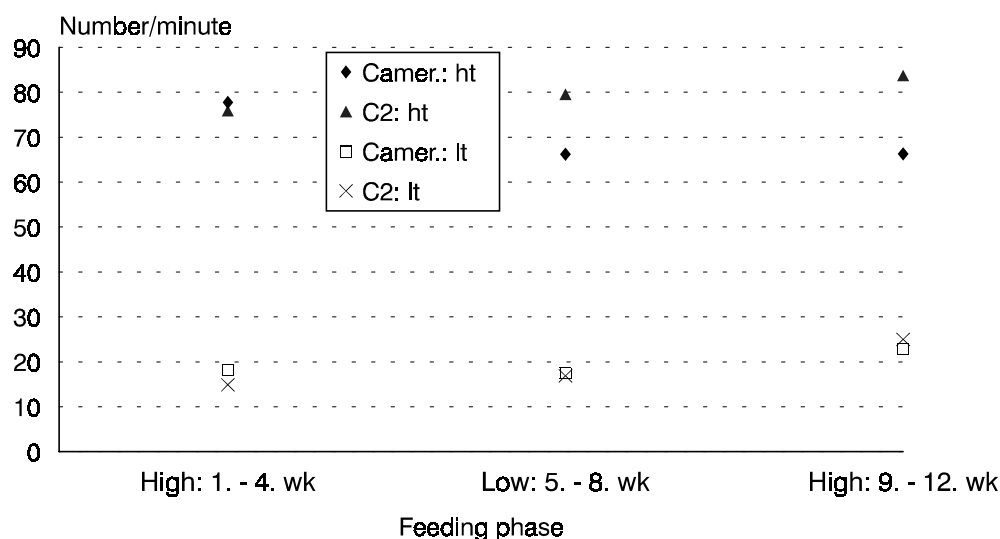


Fig. 11: Effect of fluctuating temperatures (high and low during the day and at night, respectively) on breathing rate of Cameroon and Cameroon x Mutton lambs during the post-weaning growth phase

Fig. 11 shows the breathing rate of the Cameroon lambs and the C2 (Cameroon X Mutton) crosses measured at 12⁰⁰ hrs during the day at 31°C/50%RH ambient temperature. Breathing rate measured at 12⁰⁰ hrs was always higher for the C2 crosses compared with the Cameroon. The Cameroon exhibited a decline from 1- 4 weeks to 5 - 8 and 9 - 12 weeks. The C2 exhibited a slight increase during the same period. Large differences in breathing rate between the Cameroon and the C2 crosses occurred during 5 - 12 weeks i. e. during the Low feeding phase (5 - 8 weeks) and during the second High phase (9 - 12 weeks).

Fig. 11 also shows the breathing rate of the Cameroon lambs and the C2 (Cameroon X Mutton) crosses measured at 20⁰⁰ hrs and at 15°C/70%RH ambient temperature. Neither genotype nor sex had any significant effect on breathing rate per minute measured at 20⁰⁰ hrs. The Cameroon recorded a slightly higher value than the C2 crosses from 1 - 4 weeks to 5 - 8 weeks. After that, the Cameroon recorded a lower value during 9 - 12 weeks than the C2 crosses. It is hereby noted that towards the end of the twelve (12) week period under caged conditions, the lambs tended to be easily excited during the evening when ambient temperature was lower than during the day. They were often excited and therefore readily engaged in mock fights and this might have an effect on the quality of the measurements and especially of breathing rate.

5.4 Carcass evaluation

Carcass evaluation was done in order to measure productive performance as effected by various treatments in terms of absolute and relative weight of muscle, fat and bones of the seven selected valuable parts, as well as the effects of the same on carcass quality and the weight of the digestive organs, blood, coat and lungs.

5.4.1 Influence of different feeding levels on performance

The analysis of variance showing the effects of treatment, genotype and sex on carcass value is shown in Table 17. Corresponding means are shown in Table 18.

Carcass traits: The effect of treatment on warm and cold dressed weight was not significant. That of genotype was highly significant but that of sex was not. The model explains 0.73 of the variation. The coefficient of variation

was about 15% for both traits. The effect of treatment on cooling losses was not significant, that of genotype on the same was very significant whereas that of sex was not. Carcasses of the C1 and C2 crosses were significantly heavier than those of the Cameroon as expected. Differences between the crosses were not significant but the C2 weighed more than the C1. Cooling losses were significantly higher in the Cameroon than in the C1 and C2 crosses. The difference between the C1 and C2 crosses was not significant.

The effect of treatment on relative weight of each carcass part to the weight of the Right Half and on the relative weight of muscle, fat and bones to the weight of the carcass part from which they were dissected, was for the most part not significant except in the case of the weight of bones of the foreleg. The difference between High-Low and Low-High treatments was significant in favour of the former. Thus large differences in the type of feeding had largely no effect on the proportionate weight of muscle, fat and bones to the Right Half or the respective carcass parts.

Significant effects of genotype and sex on carcass traits reflected higher values of absolute weight of muscle and bones for the C2 crosses than for the C1 and the Cameroon and higher values for the males than for the females. The C1 crosses gained more fat than either C2 crosses or the Cameroon. Differences between the crosses (C1 and C2) were almost always significant. Males recorded a heavier weight of muscle and bones than females. In the case of absolute weight of fat, females recorded higher values than males, although the difference between them was not significant.

The effect of treatment on relative weight of each carcass part to the weight of the Right Half and on the relative weight of muscle, fat and bones to the weight of the carcass part from which they were dissected, was for the most part not significant except in the case of the weight of bones of the foreleg. The difference between the High-Low and the Low-High treatments was significant in favour of the former. Thus large differences in the type of feeding had largely no effect on the proportionate weight of muscle, fat and bones to the Right Half or the respective carcass parts.

Significant effects of genotype and sex on relative weight of each carcass part to the weight of the Right Half and on the relative weight of muscle, fat and bones to the weight of the carcass part from which they were dissected shows much variation as follows:

- For relative weight of each carcass part to the weight of the Right Half the C1 crosses had a significantly higher proportion of back and hindleg than both the Cameroon and the C2 crosses. The difference between the Cameroon and the C2 crosses was not significant. On the other hand, the Cameroon and the C2 recorded a significantly higher proportion of middle and neck than the C1 crosses. Females recorded a higher proportion of hindleg than males. Males then recorded a higher proportion of neck than females.
- For relative weight of muscle to the weight of the carcass part from which it was dissected, the C2 crosses recorded a significantly higher proportion of muscle in the foreleg and the neck than both the Cameroon and the C1 crosses. The difference between the Cameroon and the C1 crosses was not significant. The C1 crosses recorded a significantly higher proportion of muscle in the back than both the Cameroon and the C2 crosses. The difference between the Cameroon and the C2 crosses was not significant. Both the C1 and C2 crosses recorded a significantly higher proportion of muscle in the breast than the Cameroon. The difference between the C1 and the C2 crosses was not significant. The males recorded a significantly higher proportion of muscle in the neck than the females.
- For relative weight of fat to the weight of the carcass part from which it was dissected, the Cameroon and the C1 crosses recorded a significantly higher proportion of fat in the foreleg, back, breast and hindleg than the C2. The difference between the Cameroon and the C1 crosses was not significant. The Cameroon recorded a significantly higher proportion of fat in the middle than both the C1 and C2 crosses. The difference between the C1 and the C2 crosses was significantly higher in favour of the former. The Cameroon recorded a significantly higher proportion of fat in the neck and thinning than both the C1 and C2 crosses. The difference between the crosses was not significant. The females recorded a significantly higher proportion of fat in the back, breast and hindleg than the males.

Carcass quality traits: Significant differences in carcass quality were recorded for light reflection score and fluid content. The effect of genotype on light reflection score was significant. The C2 crosses recorded significantly higher values than the C1 crosses. The effect of treatment, genotype and sex on fluid content was significant. Fluid content was significantly higher in the Low-High treatment than in the High-Low one, in the C1 than in both the Cameroon and the C2 crosses, and higher in the males than in the females.

Table 17: Results of ANOVA of absolute and relative weights of important parts of the carcass of lambs and of measures of carcass quality, 1995

Trait DF	Treatment	Genotype	Sex	R-SQ	CV (%)
	1	2	1		
1. Carcass value					
Warm carcass, kg	ns	***	ns	0.73	15.10
Cooling losses (%)	ns	**	ns	0.39	11.21
Dressing out %	ns	***	ns	0.44	3.91
Area of MLD (13 th rib), cm ²	ns	***	ns	0.70	15.02
2. Proportion to Right Half (%)					
2.1 Carcass part: Right Half					
Foreleg	ns	ns	ns	0.14	4.91
Back	ns	*	ns	0.33	5.03
Breast	ns	ns	ns	0.15	6.64
Hindleg	ns	*	*	0.36	3.59
Middle	ns	**	ns	0.40	7.38
Neck	ns	*	***	0.55	10.59
Thinning	ns	ns	ns	0.18	10.86
2.2 Muscle: Right Half					
Foreleg	ns	*	ns	0.30	7.40
Back	ns	**	ns	0.45	6.52
Breast	ns	*	ns	0.27	12.93
Hindleg	ns	***	ns	0.55	4.76
Middle	ns	ns	ns	0.10	17.24
Neck	ns	***	***	0.68	10.89
Thinning	ns	ns	ns	0.08	18.97
2.3 Fat: Right Half					
Foreleg	ns	***	ns	0.49	21.02
Back	ns	**	**	0.46	23.05
Breast	ns	*	*	0.29	22.84
Hindleg	na	***	*	0.52	18.45
Middle	ns	***	ns	0.62	22.51
Neck	ns	***	ns	0.51	13.30
Thinning	ns	*	ns	0.24	28.00
2.4 Bones: Right Half					
Foreleg	*	ns	ns	0.29	12.28
Back	ns	ns	ns	0.24	10.60
Breast	ns	ns	ns	0.18	13.43
Hindleg	ns	ns	ns	0.09	10.26
Middle	ns	ns	ns	0.18	37.77
Neck	ns	ns	ns	0.23	31.51

*** p≤0.001; ** p≤0.01; * p≤0.05; ns for not significant

Continuation: Table 17:

Trait DF	Treatment	Genotype	Sex	R-SQ	CV (%)
	1	2	1		
3. Proportion to carcass part (%)					
3.1.1 Muscle of foreleg: foreleg	ns	***	ns	0.50	4.59
3.1.2 Fat of foreleg: foreleg	ns	***	ns	0.45	22.70
3.1.3 Bones of foreleg: foreleg	*	ns	ns	0.23	11.23
3.2.1 Muscle of back: back	ns	***	**	0.54	5.48
3.2.2 Fat of back : back	ns	**	**	0.46	20.49
3.2.3 Bones of back: back	ns	*	ns	0.39	11.11
3.3.1 Muscle of breast: breast	ns	*	*	0.33	9.34
3.3.2 Fat of breast: breast	ns	*	*	0.31	22.15
3.3.3 Bones of breast: breast	ns	ns	ns	0.16	9.98
3.4.1 Muscle of hindleg: hindleg	ns	***	ns	0.62	2.64
3.4.2 Fat of hindleg: hindleg	ns	***	ns	0.49	20.04
3.4.3 Bones of hindleg: hindleg	ns	*	ns	0.32	7.37
3.5.1 Muscle of middle: middle	ns	ns	ns	0.12	15.44
3.5.2 Fat of middle: middle	ns	***	ns	0.59	21.15
3.5.3 Bones of middle: middle	ns	ns	ns	0.13	43.87
3.6.1 Muscle of neck: neck	ns	***	**	0.61	6.69
3.6.2 Fat of neck: neck	ns	***	**	0.56	20.60
3.6.3 Bones of neck: neck	ns	ns	ns	0.16	20.88
3.7.1 Muscle of thinning: thinning	ns	ns	ns	0.18	14.42
3.7.2 Fat of thinning: thinning	ns	ns	ns	0.18	26.96
4. Quality traits					
Light reflection (Goefo)	ns	*	ns	0.70	4.88
pH for MLD, 1.5 hrs	ns	ns	ns	0.10	5.50
pH for MLD, 24 hrs	ns	ns	ns	0.22	4.74
pH for MSM, 1.5 hrs	ns	ns	ns	0.20	4.65
pH for MSM, 24 hrs	ns	ns	ns	0.16	4.50
Fluid content of muscle	*	*	*	0.44	10.37
5. Digestive organs, g					
Intestinal tract	***	***	**	0.79	10.37
Intestines	***	***	**	0.73	14.49
Rumen	**	***	ns	0.55	13.80
Reticulum	**	***	ns	0.63	12.79
Omasum	ns	***	ns	0.49	17.47
Abomasum	**	***	*	0.72	15.47
Liver	***	***	ns	0.82	12.26
Pancreas	***	***	**	0.64	19.45
Pharynx	***	***	ns	0.60	14.97
6. Intestinal contents:full tract (%)	ns	*	ns	0.32	8.54
7. Organs of thermoregulation, g					
Blood	*	***	ns	0.57	17.88
Coat	ns	***	ns	0.57	16.59
Lungs	*	***	*	0.67	15.57

*** p≤0.001; ** p≤0.01; * p≤0.05; ns for not significant

Table 18: Means and standard errors of absolute and relative weights of important parts of the carcass of lambs and of measures of carcass quality, 1995

Trait	N:	Treatment High-Low 15	Low-High 15	Genotype Cameroon 10	C1 10	C2 10	Sex Male 14	Female 16
1. Carcass value								
Warm carcass, kg		11.92a±0.85	12.86a±0.89	8.63a±0.45	13.47b±0.89	15.07b±0.28	12.00a±0.92	12.72a±0.82
Cold dressed weight, kg		11.54a±0.83	12.43a±0.86	8.32a±0.44	13.06b±0.87	14.59b±0.28	11.61a±0.90	12.31a±0.81
Dressing out %		49.76a±0.75	49.31a±0.51	47.38a±0.66	50.21b±0.67	51.03b±0.47	48.62a±0.66	50.34a±0.55
Area of MLD(13 th rib), cm ²		11.12a±0.75	11.99a±0.82	8.54a±0.48	13.96b±0.86	12.66b±0.48	11.64a±0.79(13)	11.49a±0.80(15)
2. Proportion to Right Half (%)								
2.1 Carcass part: Right Half								
Foreleg		16.86a±0.23	16.60a±0.19	16.92a±0.21	16.36a±0.34	16.92a±0.18	16.81a±0.28	16.66a±0.15
Back		15.98a±0.24	16.41a±0.24	16.15a±0.27	16.70b±0.20	15.74a±0.34	15.95a±0.26	16.41a±0.22
Breast		14.43a±0.32	14.31a±0.16	13.94a±0.19	14.77a±0.43	14.41a±0.21	14.22a±0.34	14.50a±0.15
Hindleg		33.54a±0.33	33.60a±0.40	32.63a±0.50	34.19b±0.34	33.89a±0.34	32.98a±0.43	34.09b±0.25
Middle		6.00a±0.15	5.85a±0.13	6.28a±0.13	5.54b±0.07	5.96a±0.19	6.07a±0.16	5.80a±0.11
Neck		8.62a±0.37	8.32a±0.27	9.16a±0.42	7.77b±0.20	8.48a±0.41	9.23a±0.36	7.80b±0.16
Thinning		4.57a±0.14	4.91a±0.13	4.93a±0.15	4.67a±0.21	4.61a±0.14	4.74a±0.14	4.74a±0.14
2.2 Muscle: Right Half								
Foreleg		11.19a±0.30	11.29a±0.17	10.82a±0.18	11.01a±0.37	11.88b±0.19	11.31a±0.32	11.18a±0.17
Back		9.76a ±0.21	10.08a ±0.21	9.29a ±0.23	10.45b ±0.18	10.02a ±0.23	10.01a ±0.23	9.84a ±0.20
Breast		7.80a±0.38	7.80a±0.16	7.10a±0.20	8.10b±0.47	8.20b±0.21	7.95a±0.35	7.67a±0.22
Hindleg		24.69a±0.42	24.52a±0.43	22.99a±0.32	25.16b±0.42	25.66b±0.33	24.21a±0.47	24.95a±0.36
Middle		3.80a ±0.23	3.91a ±0.07	3.91a ±0.08	3.72a ±0.04	3.93a ±0.36	4.02a ±0.11	3.71a ±0.20
Neck		5.24a±0.29	5.01a±0.17	5.14a±0.23	4.65a±0.20	5.58b±0.35	5.71a±0.24	4.61b±0.13
Thinning		2.99a±0.15	3.19a±0.14	2.99a±0.17	3.18a±0.20	3.10a±0.18	3.16a±0.12	3.03a±0.17
2.3 Fat: Right Half								
Foreleg		2.54a±0.17	2.48a±0.19	3.03a±0.15	2.59a±0.21	1.93b±0.12	2.52a±0.17	2.51a±0.19
Back		3.12a±0.28	3.40a±0.20	3.71a±0.26	3.43a±0.33	2.64b±0.22	2.93a±0.19	3.55b±0.26
Breast		4.05a±0.33	4.03a±0.19	4.48a±0.29	4.02a±0.39	3.62b±0.23	3.71a±0.24	4.32b±0.27
Hindleg		3.15a±0.24	3.48a±0.18	3.79a±0.21	3.52a±0.25	2.64b±0.18	3.15a±0.20	3.46b±0.22
Middle		0.80a ±0.08	0.74a ±0.06	1.02a ±0.06	0.74b ±0.06	0.55c ±0.04	0.83a ±0.08	0.72a ±0.05
Neck		1.53a±0.10	1.80a±0.15	2.10a±0.15	1.60b±0.12	1.29b±0.11	1.68a±0.17	1.65a±0.10
Thinning		1.59a±0.15	1.72a±0.10	1.94a±0.15	1.49b±0.17	1.52b±0.11	1.59a±0.14	1.71a±0.12

Means with different subscripts within rows are significantly different. Figures in brackets show changes in N

Continuation: Table 18: Means and standard errors of absolute and relative weights of important parts of the carcass of lambs and of measures of carcass quality, 1995

Trait	Treatment	Low-High	Genotype	C1	C2	Sex	Female
	High-Low		Cameroon			Male	
N:	15	15	10	10	10	14	16
3. Proportion to carcass part (%)							
3.1.1 Muscle of foreleg: foreleg	66.24a±1.13	68.03a±0.93	63.98a±0.77	67.20b±1.48	70.24c±0.58	67.16a±1.29	67.12a±0.85
3.1.2 Fat of foreleg: foreleg	15.21a±1.12	14.97a±1.13	17.96a±0.97	15.92a±1.41	11.39b±0.72	15.10a±1.13	15.08a±1.12
3.1.3 Bones of foreleg: foreleg	18.54a±0.37	17.00b±0.63	18.06a±0.77	16.88a±0.78	18.37a±0.34	17.74a±0.58	17.80a±0.53
3.2.1 Muscle of back: back	61.16a±1.31	61.48a±1.11	57.61a±1.42	62.68b±1.43	63.67b±0.65	62.77a±1.00	60.06b±1.26
3.2.2 Fat of back : back	19.33a±1.55	20.64a±1.11	22.88a±1.33	20.39a±1.82	16.68b±1.17	18.30a±1.11	21.46b±1.41
3.2.3 Bones of back: back	19.51a±0.75	17.88a±0.42	19.50a±0.77	16.93b±0.57	19.65a±0.72	18.93a±0.43	18.49a±0.77
3.3.1 Muscle of breast: breast	53.89a±1.86	54.54a±1.04	51.02a±1.55	54.70a±2.13	56.93b±1.31	55.71a±1.43	52.92b±1.48
3.3.2 Fat of breast: breast	28.18a±2.26	28.17a±1.26	32.06a±1.84	27.37b±2.64	25.10b±1.59	26.34a±1.75	29.78b±1.78
3.3.3 Bones of breast: breast	17.92a±0.45	17.29a±0.47	16.92a±0.44	17.93a±0.77	17.97a±0.39	17.96a±0.54	17.30a±0.39
3.4.1 Muscle of hindleg: hindleg	73.58a±0.74	72.94a±0.78	70.50a±0.64	73.57b±0.65	75.72c±0.60	73.36a±0.68	73.17a±0.82
3.4.2 Fat of hindleg: hindleg	9.44a±0.76	10.39a±0.56	11.62a±0.65	10.33a±0.77	7.79b±0.54	9.62a±0.66	10.17a±0.68
3.4.3 Bones of hindleg: hindleg	16.98a±0.33	16.67a±0.40	17.88a±0.49	16.10b±0.38	16.49b±0.22	17.02a±0.21	16.66a±0.45
3.5.1 Muscle of middle: middle	62.96a±3.46	66.98a±1.04	62.34a±0.85	67.25a±0.61	65.33a±5.42	66.35a±1.25	63.77a±3.25
3.5.2 Fat of middle: middle	13.27a±1.15	12.53a±0.89	16.29a±0.82	13.26b±1.04	9.15c±0.61	13.56a±1.22	12.32a±0.83
3.5.3 Bones of middle: middle	23.77a±3.48	20.50a±0.67	21.38a±1.09	19.49a±0.73	25.52a±5.13	20.10a±0.73	23.91a±3.23
3.6.1 Muscle of neck: neck	60.72a±1.76	60.33a±1.37	56.28a±1.58	59.71b±1.53	65.60c±1.36	62.10a±1.77	59.16b±1.30
3.6.2 Fat of neck: neck	18.16a±1.44	21.37a±1.43	23.06a±1.50	20.76a±1.70	15.50b±1.39	18.12a±1.58	21.20b±1.32
3.6.3 Bones of neck: neck	21.12a±1.27	18.30a±0.71	20.67a±2.02	19.53a±1.00	18.93a±0.55	19.78a±1.46	19.65a±0.69
3.7.1 Muscle of thinning: thinning	65.49a±2.98	64.83a±1.96	60.55a±2.89	68.06a±3.25	66.88a±2.68	66.84a±2.41	63.69a±2.54
3.7.2 Fat of thinning: thinning	34.51a±2.98	35.17a±1.96	39.46a±2.89	31.95a±3.25	33.12a±2.68	33.16a±2.41	36.31a±2.54

Continuation: Table 18: Means and standard errors of absolute and relative weights of important parts of the carcass of lambs and of measures of carcass quality, 1995

Trait	Treatment High-Low	Low-High	Genotype Cameroon	C1	C2	Sex Male	Female
N:	15	15	10	10	10	14	16
4. Quality traits							
Light reflection (Goefo)	62.80a±2.48	64.40a±1.75	.	61.00a±1.45 ⁵	66.20b±2.01 ⁵	63.50a±3.07 ⁴	63.67a±1.61 ⁶
pH for MLD, 1.5 hrs	5.97a±0.09	6.02a±0.08	6.03a±0.08	5.88a±0.11	6.08a±0.11	6.03a±0.08	5.96a±0.09
pH for MLD, 24 hrs	5.70a±0.07	5.61a±0.08	5.50a±0.09	5.69a±0.09	5.77b±0.07	5.68a±0.07	5.63a±0.08
pH for MSM, 1.5 hrs	5.86a±0.07	5.95a±0.08	5.96a±0.08	5.81a±0.11	5.95a±0.08	5.99a±0.08	5.83a±0.06
pH for MSM, 24 hrs	5.59a±0.07	5.61a±0.06	5.48a±0.08	5.67a±0.07	5.66a±0.09 ⁹	5.63a±0.06	5.57a±0.07(15)
Fluid content of muscle	0.42a±0.02	0.46b±0.01	0.41a±0.02	0.48b±0.01	0.43a±0.01	0.45a±0.01	0.43b±0.01
5. Digestive organs, g							
Intestinal tract	1210.87a±55.8 ⁸	1441.20b±75.1 ¹	1043.00a±50.7 ⁵	1451.60b±78.5 ¹	1483.50b±15 ^{7.60}	1342.07a±70.22	1312.00b±74.57
Intestines	604.93a±37.62	741.53b±45.70	511.20a±31.16	741.80b±51.45	766.70b±41.2 ⁸	698.07a±40.32	651.50b±48.47
Rumen	391.93a±15.24	461.27b±22.64	359.30a±16.35	463.80b±31.15	456.70b±11.9 ⁶	420.14a±23.68	432.25a±19.29
Reticulum	66.67a±2.94	75.47b±3.90	57.40a±2.81	77.20b±3.13	78.60b±3.62	70.50a±4.20	71.56a±3.14
Omasum	57.27a±3.57	59.27a±3.39	47.10a±2.16	69.40b±3.47	58.30c±3.53	57.93a±3.15	58.56a±3.72
Abomasum	85.80a±6.31	103.07b±6.23	70.10a±5.17	99.20b±5.60	114.00c±6.28	95.14a±6.16	93.81b±7.02
Liver	304.47a±14.94	421.87b±24.12	286.90a±17.88	364.50b±28.35	438.10c±25.1 ⁶	352.14a±25.93	372.81a±24.74
Pancreas	34.80a±2.42	46.40b±3.14	32.20a±2.53	41.80b±4.14	47.80b±3.27	42.36a±3.27	39.06b±3.09
Pharynx	204.53a±9.86	252.67b±12.81	191.60a±9.02	231.50b±14.67	262.70b±14.9 ⁸	220.36a±12.05	235.81a±13.55
6. Intestinal contents:full tract (%)	59.02a±1.49	56.61a±1.36	54.04a±2.27	58.95b±1.11	60.45b±1.06	58.21a±1.77	57.47a±1.16
7. Organs of thermoregulation, g							
Blood	1028.53a±61.7 ⁴	1203.53b±78.0 ⁶	887.40a±55.34	1113.30b±87.8 ⁶	1347.40c±55.92	1084.64a±81.62	1143.50a±66.82
Coat	1620.00a±105.77	1814.87a±98.7 ⁷	1325.50a±74.8 ⁵	1933.20b±116.79	1893.60b±84.25	1694.40a±105.72	1737.60a±104.77
Lungs	248.27a±17.08	278.20b±16.56	212.60a±13.56	250.80b±12.69	326.30c±17.4 ⁹	267.07a±17.76	259.88b±16.80

Means with different subscripts within rows are significantly different. Figures in brackets show changes in N

Digestive organs: The model explains 0.49 - 0.82 of the variation. The coefficient of variation was about 10 - 20% for these traits. The effect of treatment on the weight of the digestive organs was very dramatic as is reflected in the very significantly to highly significantly heavier weight of the intestinal tract, intestines, rumen, reticulum, abomasum, liver, pancreas and pharynx of the Low-High treatment compared with the High-Low one. The effect of genotype on the weight of the same was highly significant. The C1 and C2 crosses recorded highly significant weight of intestinal tract, intestines, rumen, reticulum, pancreas and pharynx than the Cameroon. The difference between the C1 and C2 crosses was not significant. The C1 crosses recorded significantly heavier weight of omasum than the Cameroon and the C2 crosses.

The difference between the Cameroon and the C2 crosses was significant in favour of the latter. The C2 crosses recorded significantly heavier weight of abomasum and liver than the Cameroon and the C1 crosses. The difference between the Cameroon and the C1 crosses was significant in favour of the former. Thus differences due to genotype were largely dictated by differences in live body weight. The effect of sex on weight of intestinal tract, intestines, abomasum and pancreas was significant in favour of the males.

Blood, coat and lungs: The effect of treatment on weight of blood was significant, that of genotype highly significant, and that of sex not significant. The Low-High treatment recorded significantly more weight of blood than the High-Low one. The C1 and C2 crosses recorded significantly more than the Cameroon. The difference between the C1 and C2 crosses was significant in favour of the latter. The effect of treatment on the weight of coat was not significant, that of genotype was highly significant, and that of sex was not significant. The C1 and C2 crosses recorded a significantly heavier weight of coat than the Cameroon. The difference between the C1 and C2 crosses was not significant. The effect of treatment on the weight of lungs was significant, that of genotype highly significant, and that of sex, significant. The C1 and C2 crosses recorded significantly heavier weight of lungs than the Cameroon. The difference between the C1 and C2 crosses was significant in favour of the latter.

5.4.2 Reaction to high ambient temperature during the day and of alternating feeding levels

The objective was to quantify the amount of muscle, fat and bones as well as the carcass quality of slaughtered male and female Cameroon lambs and C2 (Cameroon X Mutton) male and female crossbred lambs following exposure of all lambs to the above mentioned single treatment. Maximum wheat straw intake per lamb per day was limited to 200g.

The analysis of variance showing the effects of treatment, genotype and sex on carcass value is shown in Table 19. Corresponding means are shown in Table 20.

Carcass traits: The effect of genotype on warm and cold dressed weight was very significant and highly significant, respectively. The effect of sex on both traits was very significant. In both cases the model explains 0.90 of the variation. The coefficient of variation was about 11% for warm carcass and 10% for cold dressed weight.

Significant effects of genotype and sex on carcass traits reflected higher values of absolute weight of muscle and bones for the C2 crosses than for the Cameroon and higher values for the males than for the females.

In the case of absolute weight of fat, a significant difference between the Cameroon and the C2 crosses was recorded for fat in the foreleg. Significant differences in absolute weight of fat between males and females were higher in the former. Thus males tended to develop significantly more muscle, fat and bones than females.

Significant effects of genotype and sex on relative weight of each carcass part to the weight of the Right Half and on the relative weight of muscle, fat and bones to the weight of the carcass part from which they were dissected shows much variation as follows:

Table 19: Results of ANOVA of absolute and relative weights of important parts of the carcass of lambs and of measures of carcass quality, 1996

Trait DF:	Genotype	Sex	R-SQ	CV (%)
	1	1		
1. Carcass value				
Warm carcass, kg	**	**	0.90	10.71
Cooling losses (%)	ns	ns	0.62	21.73
Dressing out %	ns	ns	0.30	3.88
Area of MLD(13 th rib), cm ²	*	*	0.63	12.61
2. Proportion to Right Half (%)				
2.1 Carcass part: Right Half				
Foreleg	*	ns	0.56	3.69
Back	*	ns	0.59	5.64
Breast	ns	ns	0.08	6.80
Hindleg	**	*	0.84	2.81
Middle	ns	*	0.60	7.40
Neck	***	ns	0.83	7.60
Thinning	ns	ns	0.14	16.61
2.2 Muscle: Right Half				
Foreleg	ns	ns	0.37	5.91
Back	*	ns	0.45	6.93
Breast	ns	ns	0.18	6.85
Hindleg	***	*	0.86	4.46
Middle	ns	ns	0.26	11.31
Neck	*	**	0.79	5.76
Thinning	***	ns	0.85	7.56
2.3 Fat: Right Half				
Foreleg	ns	ns	0.06	23.76
Back	*	ns	0.58	13.77
Breast	ns	ns	0.21	27.82
Hindleg	*	ns	0.54	18.55
Middle	ns	ns	0.45	26.66
Neck	***	ns	0.85	13.64
Thinning	ns	ns	0.05	33.42

*** p<0.001; ** p<0.01; * p<0.05; ns for not significant; DF Degrees of freedom

Continuation: Table 19: Results of ANOVA of absolute and relative weights of important parts of the carcass of lambs and of measures of carcass quality, 1996

Trait DF:	Genotype	Sex	R-SQ	CV (%)
	1	1		
2.4 Bones: Right Half				
Foreleg	ns	ns	0.29	14.73
Back	ns	ns	0.12	9.10
Breast	ns	ns	0.25	11.76
Hindleg	ns	ns	0.04	8.93
Middle	ns	ns	0.10	20.43
Neck	ns	ns	0.39	32.67
3. Proportion to carcass part (%)				
3.1.1 Muscle of foreleg: foreleg	ns	ns	0.03	3.68
3.1.2 Fat of foreleg: foreleg	ns	ns	0.07	24.89
3.1.3 Bones of foreleg: foreleg	ns	ns	0.26	13.42
3.2.1 Muscle of back: back	ns	ns	0.06	4.53
3.2.2 Fat of back : back	ns	ns	0.37	12.13
3.2.3 Bones of back: back	*	ns	0.59	7.99
3.3.1 Muscle of breast: breast	ns	ns	0.20	10.32
3.3.2 Fat of breast: breast	ns	ns	0.25	22.53
3.3.3 Bones of breast: breast	ns	ns	0.37	10.54
3.4.1 Muscle of hindleg: hindleg	**	ns	0.80	2.35
3.4.2 Fat of hindleg: hindleg	*	ns	0.64	19.29
3.4.3 Bones of hindleg: hindleg	ns	ns	0.38	7.50
3.5.1 Muscle of middle: middle	ns	ns	0.12	6.36
3.5.2 Fat of middle: middle	ns	ns	0.19	29.90
3.5.3 Bones of middle: middle	ns	ns	0.05	16.95
3.6.1 Muscle of neck: neck	**	ns	0.70	6.93
3.6.2 Fat of neck: neck	*	ns	0.62	13.16
3.6.3 Bones of neck: neck	ns	ns	0.25	25.34
3.7.1 Muscle of thinning: thinning	ns	ns	0.45	14.37
3.7.2 Fat of thinning: thinning	ns	ns	0.45	15.44

*** $p \leq 0.001$; ** $p \leq 0.01$; * $p \leq 0.05$; ns for not significant; DF Degrees of freedom

Continuation: Table 19: Results of ANOVA of absolute and relative weights of important parts of the carcass of lambs and of measures of carcass quality, 1996

Trait DF:	Genotype	Sex	R-SQ	CV (%)
	1	1		
4. Quality traits				
PH for MLD, 1.5 hrs	ns	ns	0.14	4.60
PH for MLD, 24 hrs	ns	ns	0.04	1.88
PH for MSM, 1.5 hrs	ns	ns	0.39	3.95
PH for MSM, 24 hrs	*	ns	0.46	1.11
Fluid content of muscle	ns	ns	0.26	8.76
5. Digestive organs, g				
Intestinal tract	**	*	0.80	15.06
Intestines	*	ns	0.67	19.85
Rumen	**	*	0.77	13.48
Reticulum	**	ns	0.77	18.33
Omasum	**	*	0.80	17.38
Abomasum	***	*	0.90	12.96
Liver	*	**	0.73	16.62
Pancreas	*	*	0.69	18.00
Pharynx	**	*	0.81	13.36
6. Intestinal contents:full tract (%)	ns	ns	0.37	20.21
7. Organs of thermoregulation, g				
Blood	***	**	0.94	8.00
Coat	***	*	0.91	9.21
Lungs	**	*	0.84	10.65

*** $p \leq 0.001$; ** $p \leq 0.01$; * $p \leq 0.05$; ns for not significant; DF Degrees of freedom

Table 20: Means and standard errors of absolute and relative weights of important parts of the carcass of lambs and of measures of carcass quality, 1996

Trait N:	Genotype		Sex	
	Cameroon 5	C2 5	Male 6	Female 4
1. Carcass value				
Warm carcass, kg	9.31a±1.10	14.42b±1.15	13.16a±1.15	8.43b±1.53
Cooling losses (%)	3.22a±0.25	2.15a±0.39	2.46a±0.32	3.31a±0.42
Dressing out %	47.83a±0.96	49.34a±0.76	49.06a±0.60	47.40a±1.54
Area of MLD (13 th rib), cm ²	10.42a±0.69	12.74b±0.94	12.48a±0.80	10.22b±0.87
2. Proportion to Right Half, %				
2.1 Carcass part: Right Half				
Foreleg	16.28a±0.37	17.37b±0.16	16.65a±0.39	17.08a±0.31
Back	17.50a±0.50	15.65b±0.24	16.66a±0.56	16.45a±0.66
Breast	13.77a±0.27	13.87a±0.51	14.00a±0.32	13.55a±0.51
Hindleg	31.35a±0.63	34.29b±0.59	32.04a±0.69	33.98b±1.05
Middle	6.72a±0.25	6.24a±0.33	6.83a±0.22	5.96b±0.24
Neck	9.75a±0.26	7.44b±0.37	8.87a±0.52	8.19a±0.83
Thinning	4.63a±0.15	5.15a±0.46	4.96a±0.41	4.79a±0.15
2.2 Muscle: Right Half				
Foreleg	10.95a±0.27	11.70a±0.32	11.16a±0.33	11.57a±0.34
Back	10.74a±0.30	9.67b±0.30	10.20a±0.43	10.22a±0.26
Breast	7.44a±0.26	7.34a±0.20	7.24a±0.22	7.62a±0.16
Hindleg	22.09a±0.54	26.08b±0.76	23.29a±0.91	25.27b±1.38
Middle	4.43a±0.15	4.24a±0.29	4.52a±0.20	4.06a±0.21
Neck	5.08a±0.26	4.56b±0.17	5.12a±0.19	4.36b±0.09
Thinning	2.14a±0.08	2.88b±0.08	2.48a±0.16	2.55a±0.27
2.3 Fat: Right Half				
Foreleg	2.64a±0.30	2.60a±0.23	2.51a±0.20	2.78a±0.36
Back	3.94a±0.20	3.02b±0.21	3.54a±0.23	3.39a±0.42
Breast	4.07a±0.50	4.05a±0.56	4.46a±0.44	3.46a±0.52
Hindleg	3.54a±0.16	2.54b±0.30	3.12a±0.33	2.92a±0.35
Middle	0.98a±0.17	0.81a ±0.07	1.02a±0.11	0.70a±0.11
Neck	2.32a±0.15	1.34b±0.06	1.91a±0.25	1.70a±0.28
Thinning	2.49a±0.14	2.27a±0.46	2.47a±0.34	2.24a±0.31

Means with different subscripts within rows are significantly different. Figures in brackets show changes in N.

Continuation: Table 20: Means and standard errors of absolute and relative weights of important parts of the carcass of lambs and of measures of carcass quality, 1996

Trait N:	Genotype		Sex	
	Cameroon 5	C2 5	Male 6	Female 4
3. Proportion to carcass part (%)				
3.1.1 Muscle of foreleg: foreleg	67.25a±0.74	67.32a±1.29	67.01a±1.02	67.69a±0.99
3.1.2 Fat of foreleg: foreleg	16.22a±1.84	14.99a±1.45	15.09a±1.16	16.38a±2.40
3.1.3 Bones of foreleg: foreleg	16.54a±1.42	17.70a±0.55	17.90a±0.45	15.94a±1.69
3.2.1 Muscle of back: back	61.39a±0.95	61.78a±1.41	61.12a±0.82	62.28a±1.70
3.2.2 Fat of back : back	22.48a±0.69	19.28a±1.36	21.17a±0.97	20.45a±1.88
3.2.3 Bones of back: back	16.13a±0.45	18.94b±0.72	17.72a±1.03	17.27a±0.34
3.3.1 Muscle of breast: breast	54.14a±2.35	53.29a±2.79	51.89a±2.25	56.47a±2.34
3.3.2 Fat of breast: breast	29.41a±3.15	28.83a±3.18	31.69a±2.54	25.26a±3.01
3.3.3 Bones of breast: breast	16.45a±1.07	17.88a±0.63	16.43a±0.84	18.27a±0.77
3.4.1 Muscle of hindleg: hindleg	70.45a±0.55	76.01b±1.02	72.58a±1.40	74.21a±1.81
3.4.2 Fat of hindleg: hindleg	11.33a±0.68	7.44b±0.93	9.86a±1.20	8.68a±1.21
3.4.3 Bones of hindleg: hindleg	18.21a±0.43	16.55a±0.66	17.57a±0.54	17.11a±0.92
3.5.1 Muscle of middle: middle	66.03a±1.84	67.82a±1.86	66.12a±1.60	68.13a±2.19
3.5.2 Fat of middle: middle	14.42a±2.26	13.16a±1.43	15.05a±1.58	11.89a±2.01
3.5.3 Bones of middle: middle	19.55a±1.61	19.02a±1.14	18.83a±1.19	19.97a±1.65
3.6.1 Muscle of neck: neck	52.12a±2.45	61.39b±0.99	58.19a±1.66	54.60a±4.48
3.6.2 Fat of neck: neck	23.78a±1.57	17.97b±0.48	21.15a±1.71	20.46a±2.03
3.6.3 Bones of neck: neck	24.11a±3.39	20.64a±1.40	20.66a±1.59	24.95a±3.87
3.7.1 Muscle of thinning: thinning	46.28a±1.66	57.32a±4.17	50.79a±3.04	53.32a±5.88
3.7.2 Fat of thinning: thinning	53.72a±1.66	42.68a±4.17	49.21a±3.04	46.68a±5.88
4. Quality traits				
pH for MLD, 1.5 hrs	6.11a±0.11	5.93a±0.13	6.00a±0.11	6.05a±0.14
pH for MLD, 24 hrs	5.40a±0.05	5.38a±0.04	5.40a±0.04	5.38a±0.06
pH for MSM, 1.5 hrs	6.07a±0.10	5.76a±0.10	5.94a±0.13	5.88a±0.10
pH for MSM, 24 hrs	5.29a±0.03	5.19b±0.02	5.23a±0.03	5.26a±0.04
Fluid content of muscle	0.44a±0.02	0.40a±0.02	0.42a±0.01	0.42a±0.03

Continuation: Table 20: Means and standard errors of absolute and relative weights of important parts of the carcass of lambs and of measures of carcass quality, 1996

Trait	Genotype		Sex	
	Cameroon	C2	Male	Female
N:	5	5	6	4
5. Digestive organs, g				
Intestinal tract	962.20a±52.37	1515.60b±140.79	1356.50a±166.70	1062.50b±121.03
Intestines	493.60a±49.43	727.80b±78.29	678.33a±82.59	509.25a±54.25
Rumen	360.80a±26.70	494.80b±45.80	474.67a±39.61	357.50b±41.91
Reticulum	51.40a±4.96	87.80b±7.85	75.83a±10.92	60.25a±8.54
Omasum	49.60a±5.05	78.00b±9.52	73.67a±8.85	49.00b±6.65
Abomasum	67.00a±4.09	125.40b±9.56	104.67a±16.12	83.50b±12.32
Liver	299.00a±30.27	387.80b±48.50	396.67a±29.78	263.50b±36.42
Pancreas	38.00a±3.42	53.80b±5.86	51.33b±5.08	37.75b±5.22
Pharynx	199.00a±20.97	290.00b±22.08	271.67a±26.85	203.75b±23.35
6. Intestinal contents:full tract (%)	46.55a±7.62	59.89a±1.22	55.67a±3.01	51.8a3±8.71
7. Organs of thermoregulation, g				
Blood	797.00a±66.78	1266.40b±103.42	1219.20a±130.95	856.00b±100.39
Coat	1414.80a±132.27	2231.00b±87.50	1965.67a±174.69	1608.75b±280.95
Lungs	209.20a±11.10	300.80b±21.82	276.33a±24.64	223.00b±25.69

Means with different subscripts within rows are significantly different. Figures in brackets show changes in N

For relative weight of each carcass part to the weight of the Right Half the C2 crosses recorded significantly and very significantly higher proportion of foreleg and hindleg, respectively, than the Cameroon. The Cameroon recorded significantly and highly significantly higher proportion of weight of back and neck, respectively, than the C2 crosses. Females recorded a higher proportion of hindleg than the males, and the males, a higher proportion of middle than the females.

- For relative weight of muscle to the weight of the carcass part from which it was dissected, the C2 crosses recorded a highly significantly higher proportion of muscle of hindleg and thinning than the Cameroon. The Cameroon recorded a significantly higher proportion of muscle of back and neck than the C2 crosses. Females recorded a significantly higher proportion of muscle of hindleg than males, and males, a significantly higher proportion of muscle of neck than females.
- For relative weight of fat to the weight of the carcass part from which it was dissected, the Cameroon recorded a significantly higher proportion of fat in the back and hindleg than the C2

crosses, as well as a highly significantly higher proportion of fat in the neck. In this case, the Cameroon had a higher tendency for increased fat deposition than the C2 crosses.

Carcass quality traits: The effect of genotype and sex on most carcass quality traits considered was not significant except in the case of pH value of the MSM 24 hours post-mortem for which the Cameroon recorded a significantly higher value than the C2 crosses.

Digestive organs: The model explains 0.67 - 0.90 of the variation for weight of digestive organs. The coefficient of variation was about 13 - 20%. For weight of all the digestive organs considered, the C2 crosses recorded significantly to highly significantly heavier weights than the Cameroon. The males recorded significantly to very significantly heavier weight than the females for all digestive organs except the intestines and the reticulum.

Blood, coat and lungs: The effect of genotype on weight of blood was highly significant, and that of sex, very significant. The effect of genotype on weight of coat was highly significant, and that of sex, significant. The effect of genotype on weight of lungs was very significant, and that of sex, significant. The C2 crosses recorded significantly heavier weight than the Cameroon, and the males significantly heavier than the females.

5.4.3 Distribution of internal fat in response to different levels of feeding under stall temperature conditions (1995) and high ambient temperature during the day with alternating feeding levels (1996)

Table 21 shows the analysis of variance and means and standard errors of relative and absolute fat of the carcasses with regard to total fat*, internal fat (kidney fat and mesenteric fat together), kidney and mesenteric fat. The distribution of this fat has been referred to under each treatment as follows:

Influence of different feeding levels on performance: The effect of treatment on the proportion of total fat to dead weight was not significant under stall ambient temperature conditions. The effect of genotype on the same was significant and that of sex, very significant. The model explains 0.41 of the variation for this trait. The coefficient was 20.59%. The Cameroon had a significantly higher proportion of this fat than the C1 and C2 crosses. The difference between the C1 and C2 crosses was not significant. The difference between the males and the females was significant in favour of the latter.

Treatment did not effect the proportion of kidney and mesenteric fat significantly. The effect of genotype on the proportion of kidney fat was highly significant and that of sex, significant. The Cameroon had a significantly higher proportion than the C1 and C2 crosses. The difference between the C1 and C2 crosses was not significant. The difference between the males and the females was significant in favour of the latter.

The effect of genotype on the proportion of mesenteric fat was significant and that of sex was very significant. The Cameroon and the C2 crosses recorded a significantly higher value than the C1 crosses. The difference between the Cameroon and the C2 crosses was not significant. The difference between the males and the females was significant in favour of the latter.

Reaction to high ambient temperature during the day and of alternating feeding levels: The effect of genotype on the proportion of mesenteric fat was very significant and that of sex was not. The model explains 0.75 of the variation for this trait. The coefficient of variation was 13.98%. The Cameroon had a significantly higher proportion than the C2 crosses. The difference between the males and the females was significant but males recorded a higher value this time than the females. A similar reaction can be seen in the case of the proportion of kidney and mesenteric fat.

Looking at the absolute values, it can be seen that under the temperature treatment, large differences between the Cameroon and the C2 crosses occurred with regard to kidney fat, and that those between the males and females occurred with regard to mesenteric fat (see Table 21).

The amount of fat stored in the kidney and in the stomach and intestines following High-Low and Low-High feeding where both treatments were characterised by a similar level and length of feed restriction shows low levels of coefficient of determination for both kidney and mesenteric fat. The Low feeding phase therefore tended to limit the amount of internal fat deposited. Nevertheless, Low-High feeding tended to raise the amount of internal fat deposited compared High-Low feeding.

Table 21: Results of ANOVA of relative deposition of total fat*, kidney and mesenteric fat of slaughtered lambs by treatment, genotype and sex in 1995 and 1996

Experiment			Reaction to high ambient temperature during the day and alternating feeding levels		
Influence of different feeding levels					
1. Total fat: D-wt**	DF	$p \leq 0.05$	1. Total fat: D-wt**	DF	$p \leq 0.05$
Treatment	1	ns	Treatment	N/A	N/A
Genotype	2	*	Genotype	1	**
Sex	1	**	Sex	1	ns
R-SQ		0.41	R-SQ		0.75
CV(%)		20.59	CV(%)		13.98
2. Internal fat: D-wt	DF	$p \leq 0.05$	2. Internal fat: D-wt	DF	$p \leq 0.05$
Treatment	1	ns	Treatment	N/A	N/A
Genotype	2	**	Genotype	1	***
Sex	1	**	Sex	1	ns
R-SQ		0.46	R-SQ		0.92
CV(%)		24.46	CV(%)		12.46
3. Kidney fat: D-wt	DF	$p \leq 0.05$	3. Kidney fat: D-wt	DF	$p \leq 0.05$
Treatment	1	ns	Treatment	N/A	N/A
Genotype	2	***	Genotype	1	***
Sex	1	*	Sex	1	ns
R-SQ		0.54	R-SQ		0.91
CV(%)		23.63	CV(%)		14.91
4. Mesenteric fat: D-wt	DF	$p \leq 0.05$	4. Mesenteric fat: D-wt	DF	$p \leq 0.05$
Treatment	1	ns	Treatment	N/A	N/A
Genotype	2	*	Genotype	1	***
Sex	1	**	Sex	1	ns
R-SQ		0.42	R-SQ		0.88
CV(%)		26.53	CV(%)		14.63

*** $p \leq 0.001/0.0001$ or less; ** $p \leq 0.01$; * $p \leq 0.05$; ns for not significant. Means with different subscripts within rows are significantly different. Figures in brackets show the size of N; NB : ** Dead weight, D-wt, is defined here as fasting weight less intestinal contents and blood; * Total fat does not include fat in the head and feet

The C2 deposited the highest amount of kidney fat followed by the Cameroon and lastly the C1. The C2 crosses also deposited the highest amount of mesenteric fat followed by the C1 and then lastly the Cameroon. Again females tended to deposit more kidney and mesenteric fat than the males.

The Low phase of feeding therefore had the effect of narrowing the difference in the deposition of internal fat between the treatments and the genotypes and sexes. Nevertheless, the trend for the C2 crosses to deposit more internal fat than the C1 crosses and for the females to deposit more than the males is obvious.

In the temperature treatment, the amount of kidney fat deposited by the pure Cameroon was significantly higher than that by the C2 crosses. The amount of mesenteric fat also tended to be higher in the Cameroon than in the C2 crosses although the difference between them was not significant. Compared with the situation under stall ambient temperature conditions, males deposited a relatively higher amount of kidney fat and a significantly higher amount of mesenteric fat than the males in absolute terms.

Table 22: Relative means and standard errors reflecting the pattern of deposition of total fat*, kidney and mesenteric fat of slaughtered lambs by treatment, genotype and sex in 1995 and 1996.

Trait Relative weight (%)	Year	Experiment	Mean±se Treatment		Genotype			Sex	
			1	2	Cameroo n	C1	C2	Male	Female
1. Total fat: D-wt**	1995	Influence of different feeding levels	9.63a ±0.73(15)	9.94a ±0.53(15)	11.24a ±0.70⑩	8.98b ±0.88⑩	9.14b ±0.53⑩	8.82a ±0.58(14)	10.63b ±0.60(16)
	1996	Reaction to high ambient temperature during the day and of alternating feeding levels	N/A	N/A	11.99a ±0.55④	N/A	8.20b ±0.70⑤	10.14a ±1.25⑤	9.57a ±1.07④
2. Internal fat: D-wt	1995	Influence of different feeding levels	4.85a ±0.44(15)	5.02a ±0.36(15)	5.87a ±0.44⑩	3.96b ±0.49⑩	4.98b ±0.34⑩	4.31a ±0.39(14)	5.48b ±0.35(16)
	1996	Reaction to high ambient temperature during the day and of alternating feeding levels	N/A	N/A	6.67a ±0.29④	N/A	3.37b ±0.26⑤	4.83a ±0.97⑤	4.84a ±0.81④
3. Kidney fat: D-wt	1995	Influence of different feeding levels	1.69a ±0.16(15)	1.98a ±0.14(15)	2.30a ±0.18⑩	1.46b ±0.15⑩	1.74b ±0.14⑩	1.65a ±0.16(14)	1.99b ±0.14(16)
	1996	Reaction to high ambient temperature during the day and of alternating feeding levels	N/A	N/A	2.48a ±0.08④	N/A	1.16b ±0.13⑤	1.62a ±0.35⑤	1.79a ±0.36④
4. Mesenteric fat: D-wt	1995	Influence of different feeding levels	3.16a ±0.29(15)	3.04a ±0.23(15)	3.57a ±0.28⑩	2.50b ±0.36⑩	3.24a ±0.23⑩	2.66a ±0.25(14)	3.49b ±0.23(16)
	1996	Reaction to high ambient temperature during the day and of alternating feeding levels	N/A	N/A	4.20a ±0.22④	N/A	2.21b ±0.21⑤	3.13a ±0.62⑤	3.05a ±0.46④

*** $p \leq 0.001/0.0001$ or less; ** $p \leq 0.01$; * $p \leq 0.05$; ns for not significant. Means with different subscripts within rows are significantly different. Figures in brackets show the size of N

NB : ** Dead weight, D-wt, is defined here as fasting weight less intestinal contents and blood

* Total fat does not include fat in the head and feet

6 Discussion

6.1 Comparative pre-weaning growth performance of lambs of different genotypes

The weight measurements show that the pre-weaning growth performance of the crossbred lambs was superior to that of the pure Cameroon. Although the difference between the C1 and the C2 crosses was not significant, the pre-weaning growth performance of the C2 crosses was always superior.

Crossbred lambs (C1 and C2) exhibited significantly heavier birth weight and pre-weaning ADG than the Cameroon lambs. The C1 had a significantly heavier birth weight than the C2. From birth to weaning, however, the C2 recorded higher weight gain than the C1 but failed to be significant at $p \leq 0.05$.

The superior performance of crossbred lambs (C1 and C2) over pure Cameroon lambs with regard to live weight and growth rate is supported by results from literature indicating that crossbreeding of local tropical breeds with exotic ones selected for high productivity does increase animal productivity under tropical conditions. Increased performance has been in the form of higher ADG, birth weight, weight at slaughter and feed efficiency (NGERE, 1973; NGERE and ABOAGYE, 1981; MOHAN *et al.*, 1985; FERNANDES and DESHMUKH, 1986; ABEBE, 1996; GATENBY *et al.*, 1997). However, in order to avoid problems of adaptation to the tropical environment of animals with a temperate origin (BIANCA, 1976) or their crosses for that matter, preliminary tests to determine their suitability may have to be done where possible. The trend of the C2 to achieve relatively heavier weights and higher ADG during the pre-weaning phase may also suggest their suitability under tropical conditions where the availability of feed is seasonal and thus not ensured throughout the year. In such a situation, a combination of fast growth at a time when milk is readily available might help to offset the adverse effects of seasonal feed restriction later. Average Daily Gain estimated from 0 - 30, 30 - 60 and 60 - 90 days of age during pre-weaning growth showed the growth pattern of the crosses to be characterised by highest values from 0 - 30 days of age and lower values thereafter whereas that of the Cameroon tended to be constant during all three phases. As already mentioned in the case of the C2 crosses, high ADG values during pre-weaning growth combined with high milk performance of the ewe would constitute suitability for production in environments characterised by natural feed restriction.

6.2 Milk yield performance of Cameroon and C1 ewes using the suckling method

The milk yield experiment using the milk suckling method shows that the C1 ewes could yield 2 - 3 times more milk than the pure Cameroon ewes. The milk yield of the C1 ewes was highest at the beginning of lactation but declined gradually up to weaning. The Cameroon had a lower level of performance with higher persistence. The high milk performance of the C1 ewes at the beginning of lactation might increase the pre-weaning growth rate of the lambs. The model fails to explain most of the variation after the third week and there is a double increase in the coefficient of variation during this period. It appears that the number of animals considered was too small to ensure adequate analysis of data after the third week of lactation.

METZ *et al.* (1985) and METZ (1990) also recorded higher ($p=0.001$) milk yields in C1 crosses between the local Malaysian Katjang goat and the German Fawn over the pure Katjang. The lactation behaviour of the C1 ewes up to nine (9) weeks in the current work does not confirm the statement by PETERS and LAES-FETTBACK (1995) that higher milk yield is associated with lower persistence. It would appear that the length of lactation in the current work was not long enough to prove this point.

Though recommended as a suitable method to study the lactation of non-dairy breeds of sheep, the lamb-suckling method is tedious and time-consuming and involves excessive handling that could affect milk let down (COOMBE *et al.*, 1960). For the sake of accuracy, most studies employing this method have been carried out over the first 10 weeks of lactation. Comparison of the lamb-suckling method and oxytocin (5 IU) followed by hand milking showed very significant ($p < 0.01$) increases in yield using the latter method over a period of 10 weeks. According to OWEN (1957) separation of the lamb from the ewe may have the effect of depressing milk yield. DONEY *et al.* (1979) compared milk yield of ewes using the suckling and oxytocin methods and recorded a

highly significant ($p < 0.001$) difference in favour of the latter. The difference was more pronounced during the first week of experimentation most likely due to failure by the lambs to consume all the milk available. Milk consumption by twin lambs and single lambs tended to be similar during the first week. PEART *et al.* (1972) found that differences in milk yield of single-, twin-, triplet- and quadruplet-suckled ewes occurred during the first three weeks of lactation. The lamb-suckling method though implying the problem of residual milk (up to 23% compared with the oxytocin method according to POULTON and ASHTON, 1972) is all the same still regarded as practical for non-dairy ewes because it reflects milk consumption (WALLACE, 1948; OWEN, 1957; COOMBE *et al.*, 1960).

The milk yield of the C1 and the Cameroon ewes referred to here does not therefore reflect potential yield. It is, however, important as a reflection of milk consumption of the lambs which was higher for the C2 lambs than for the Cameroon ones. The higher pre-weaning growth rate of the C2 crosses already discussed above should have presented an added advantage compared with the pure Cameroon.

6.3 Comparative post-weaning growth performance of lambs of different genotypes

6.3.1 Influence of different feeding levels on performance

Post-weaning growth performance: Subjecting one group of lambs to High-Low and Low-High feeding caused significant differences in end-weight and ADG over the whole experimental period. Low-High feeding resulted in significantly higher end-weight and ADG over the whole experimental period than High-Low feeding. Treatment did not affect intake of total energy over the whole experimental period, however, lambs subjected to Low-High feeding consumed highly significantly more than those subjected to High-Low feeding during 7 - 12 weeks. Thus Low-High feeding was associated with some compensatory growth which was largely the result of increased intake of energy from concentrated feed during the High phase of feeding, more especially during 8 - 12 weeks. Intake of concentrated feed was not significantly different between treatments during Week 7 despite significantly higher ADG still in favour of the Low-High treatment.

The C1 and C2 crosses had significantly higher ADG than the Cameroon. The C1 crosses had higher ADG than the C2 although the difference between them failed to reach significance at $p \leq 0.05$. The C2 achieved higher ADG than the C1 during the first six (1 - 6) weeks of the experiment although the difference between them was not significant. The C1, however, had significantly ($p \leq 0.01$) higher ADG than the C2 during the last six (7 - 12) weeks of the experiment. Thus the C2 could still exhibit higher growth rate than the C1 during the early part of post-weaning growth. This trend was also observed during pre-weaning growth. In terms of end-weight, the C2 crosses were still heavier than the C1 although the difference between them failed to reach significance at $p \leq 0.05$. Thus the heavier live weight of the C2 crosses during pre-weaning growth put them at better advantage than the C1 crosses during post-weaning growth that was characterised by the Low phase of feeding.

Although intake of total energy by C1 and C2 crosses was significantly higher than that by the Cameroon and that by the C2 significantly higher than that by the C1 due to differences in live body weight on the basis of which feed restriction was calculated, intake of energy above maintenance level, though not significant, was highest for the Cameroon, followed by the C2 crosses and lastly, by the C1 crosses.

Relative intake of wheat straw by the C1 and C2 crosses was higher than by the Cameroon during the High phase of feeding but this was the reverse during the Low phase of feeding. Increased consumption of wheat straw by the C1 and C2 crosses seems to have been tied up with a higher level of feeding.

With regard to the combined effect of both feeding level and genotype, the C1 and C2 of both feeding treatments recorded significantly higher end-weight than the Cameroon. The difference in end-weight between the Cameroon of both feeding treatments was not significant; that between the crosses of both feeding treatments was also not significant. However, lambs in the Low-High treatment group had comparatively higher end-weight than those of the High-Low one. The C1 and C2 of the Low-High feeding treatment achieved the highest ADG values in that order; followed by the C1 of the High-Low treatment and the Cameroon of the Low-High treatment; and lastly the C2

and Cameroon of the High-Low treatment, again in that order. The close comparison between the latter two genotypes is due to the heavy loss in weight suffered by the C2 following change-over to the Low phase of feeding. The combined effect of both feeding level and genotype on energy intake per kg metabolic weight and energy intake above maintenance was not significant. However, the Cameroon lambs and those of the Low-High feeding treatment tended to have a higher level of consumption than the others.

Carcass evaluation: Treatment caused no significant difference in the weight of muscle, fat and bones of the seven selected valuable cuts although the lambs subjected to Low-High feeding demonstrated compensatory growth tended to record higher values than those subjected to High-Low feeding except for weight of fat and bones of the middle where it was the reverse. Cooling losses were significantly higher in the Cameroon than in the C1 and C2 crosses. Significant weight increases in response to compensatory growth were largely limited to the digestive organs (except for weight of omasum) i. e. intestinal tract, intestines, rumen, reticulum, abomasum, liver, pancreas, pharynx; as well as blood and lungs.

Low-High feeding and subsequent compensatory growth was associated with significantly higher fluid content. The fluid content of the C1 was significantly higher than that of the C2 and the Cameroon and that of the males significantly higher than that of the females.

Compared with the Cameroon, the C2 produced the heaviest carcass half followed by the C1. Wide differences between the C1 and the C2 crosses occurred in favour of the C2. The C2 would thus seem to be the animal of choice where post-weaning rearing involved an element of Low feeding.

Females had a heavier carcass weight than males although the difference between them failed to be significant at $p \leq 0.05$.

Relative weight of carcass part to weight of Right Half and weight of muscle and fat to carcass part from which it was dissected showed some variation largely due to genotype and sex. The effect of treatment, genotype and sex on carcass quality was mainly not significant except with regard to fluid content for which significant ($p \leq 0.05$) effect of treatment, genotype and sex was recorded in favour of the Low-High, C2 crossbred lambs and males; and with regard to light reflection score for which the C2 recorded a significantly ($p \leq 0.05$) higher value than the C1 crosses. SAÑUDO *et al.* working with light (10 - 12kg) and medium weight carcasses of Rosa Aragonesa, Lacaune and German Merino lambs could not confirm any increase in carcass weight that could either be associated with any relative increase in the amount of fat or reduced amount of muscle due to an allometric relationship in the growth of these tissues. The same workers, however, associated increased fluid content (excudativeness) with late maturity. Their association of lower growth rate in the Rosa Aragonesa with a darker colour due to a higher quantity of pigments as a result of increased fat deposition that causes a lower transfer of oxygen to the muscles, disagrees with current findings in which the C2 recorded significantly ($p \leq 0.05$) higher reflection score than the C1 despite the tendency of the latter to exhibit higher post-weaning growth.

Considered over the whole twelve (12) week period, Low-High feeding did not involve any significant increase in feed consumption. This agrees with the findings made by HADINOTO (1984) and may be explained by the fact that growth hormone levels (DRIVER and FORBES, 1981; HEYDEN *et al.* 1993) as well as those of plasma urea (HEYDEN *et al.*, *ibid.*) are higher during the Low phase than during High phase of feeding. It somewhat disagrees with results of other workers (KEENAN *et al.*, 1970; McMANUS *et al.*, 1972; DREW and REID, 1975c; THORNTON *et al.*; 1979) most likely because animals in these experiments often suffered considerable weight loss. Nevertheless, fast growth rate demands increased feed intake whose increased efficiency of utilisation might be enhanced as a result of efficient function of the digestive system immediately after the restriction phase (KEENAN *et al.*, *ibid.*; HADINOTO *ibid.*).

The literature considered so far does not mention or define any short period phenomenon with influence on feed intake, metabolic activity or growth of animals. HOGG (1991) stresses, however, that compensatory growth should not be seen as a phenomenon completely different from normal growth. And RYAN (1990) concludes that maintenance requirement during realimentation seems to vary from time to time. HAYDEN *et al.* (1993) describe the occurrence of compensatory growth during realimentation as transient. DRIVER and FORBES (1981) recorded periodic peak secretions of growth hormone (GH) whereby GH levels tended to be high at times of feed intake; and feed

removal for a period of ten (10) hours prompted an increase in the size and frequency of GH peaks.

The intensity of growth rate indeed varies from time to time as the current work shows. This is a natural reaction of the animals which in the natural state reflects times of abundant feed availability when higher weight gains could be made and times of seasonal feed restriction when only little gain could be made or when they could even suffer a loss in live body weight. At least from a practical point of view, some workers (PARK *et al.*, 1987; SALEM *et al.*, 1989; PARK *et al.*, 1994; CHOI *et al.*, 1997) have already conducted experiments that seem to exploit this very phenomenon. An effective balance between recurrent restriction and realimentation involving alternating 10-day periods has been reported by SALEM *et al.*, *ibid.*). There was a trend, however, for compensating animals not to recover their weight over the period of treatment. This may be explained by the short duration of the restriction phases. THOMSON *et al.* (1982) associated a long period of restriction with increased duration of compensatory growth later.

ALLDEN (1968) showed that lambs reared on a Low-High plane of nutrition during the first and second six months of life, respectively, weighed heavier than those on the High-Low plane i. e. they exhibited compensatory growth. The interest in compensatory growth has also been from the point of view of producing leaner carcasses (THORNTON *et al.*, 1979). The heavy increases in the weight of the digestive organs were followed by moderate but proportionate increases in the growth of muscle, fat and bones. WRIGHT and RUSSEL (1991) also recorded a trend for heavier weight of bone of realimented Charolais crossbred steers compared with the *ad libitum* group.

A case of proportionality (see TOUKOUROU, 1997) can thus be said to have taken place with regard to the growth of the seven selected economically valuable parts in the current work. The non-compensating group (1) subjected to High-Low feeding was not characterised by any increase in fat deposition such that a reduction in the energy balance of body organs for the compensating group is not evident here. According to KIRTON and JOHNSON (1979) bigger carcasses tend to record bigger measurements in general and with regard to weight of fat as well. Some workers have reported increased protein deposition (KEENAN *et al.*, 1970; McMANUS *et al.*, 1972; DREW and REID, 1975a; THOMSON *et al.*, 1982; LEDIN, 1983; RYAN, 1990) and water (McMANUS *et al.*, *ibid.*; LEDIN, *ibid.*) during the High phase of feeding. At the completion of realimentation i. e. High phase of feeding, no significant difference could be found between the body composition of realimented animals and those fed *ad libitum* (DREW and REID, 1975a; DREW and REID, 1975b). MARAIS *et al.* (1991) could also not associate realimentation following exposure to variable levels of feed restriction with any significant differences in protein content expressed as a percentage of body weight. The fat protein: protein ratio generally remained constant for all treatment groups (80%, 65% and 50% of *ad libitum*) except in the case of the 50% group where it was slightly high due to reduced rate of protein deposition. Nevertheless, protein deposition was reported to have increased upon realimentation. A proportionate increase in the body constituents of compensating animals has two phases: firstly one in which there is an increase in the proportions of protein and water deposited, and secondly, one in which there is an increase in fat deposition while that of protein and water reduces (WRIGHT and RUSSEL, 1991). HAYDEN *et al.* (1993) also associated increase in empty body weight and empty body protein with the initial phase of compensatory growth.

Compensatory growth is the result of a Low-High level of feeding. But any level or length of restriction that results in loss of weight and overtakes the natural ability of the animal to gain weight would not tenable in management practice.

High and low profiles of growth rate should be further studied and correlated to the mechanisms of compensatory growth as currently defined. Maximal compensatory growth potential/response if properly documented and clearly understood should help to avoid the administration of restricted feeding that overtakes the natural ability of the animals to regain weight. It should also enable feeding intervention to be made in the form of timely supplementation to avoid loss of animals where seasonal lack of feed becomes drastic or is prolonged.

6.3.2 Reaction to high ambient temperature during the day and of alternating feeding levels

Post-weaning growth performance: Subjecting Cameroon and C2 crossbred male and female lambs to High-Low High feeding i. e. three feeding levels lasting four weeks each and at 31°C/50%RH during the day and 15°C/70%RH at night caused no significant differences in ADG over the whole experimental period. However, the effect of genotype on ADG was significant during the second High phase of feeding (9 - 12 weeks). The C2 crosses which had significantly higher ADG than the Cameroon during this period were thus still able to react positively to the Low-High component despite the ambient temperature level they were subjected to. Significantly higher ADG of the C2 crosses compared with the Cameroon during 9 - 12 weeks was accompanied by significant increase in intake of total energy and concentrated feed. However, the intake of energy above maintenance level was significantly higher for the C2 crosses than for the Cameroon during 1 - 4 weeks and over the whole experimental period. Decisive for the significantly higher intake of energy above maintenance by the Cameroon compared with the C2 crosses were the first four weeks during which the latter recorded more refusals of concentrated feed and tended to consume more wheat straw. After this time, intake of concentrated feed by the C2 crosses does not seem to have been more affected than intake by the Cameroon.

Compared to the previous two experiments sex differences seem to have sharpened with regard to ADG as a result of the heat treatment with male lambs gaining significantly more than female ones during 9 - 12 weeks. This was associated with significantly higher amount of feed being consumed by males than by females during this time.

The C2 showed a higher and more stable absolute consumption of wheat straw than the Cameroon but relative wheat straw consumption of the Cameroon was higher than that of the C2 crosses during the Low and second High phases of feeding. The feeding behaviour of the lambs at 31°C/50%RH during the day and 15°C/70%RH at night was observed to be different from those reared at stall ambient temperature conditions. They required much more time to finish their daily ration of concentrated feed during the day at 31°C/50%RH than those reared at stall ambient temperature - apparently a behavioural mechanism to avoid a rapid rise in body temperature. As a result of this, the trend was to consume more straw. Concentrated feed, DM and energy intake of the males was very significantly higher than that of the females. It is clear that the feed intake of the females was more disadvantaged at 31°C/50%RH during the day and 15°C/70%RH at night than that of the males.

Rectal temperature: The C2 crosses had higher values of rectal temperature measured at 12⁰⁰ hrs with 31°C/50%RH ambient temperature than the Cameroon. Significant differences over the whole experimental period were attributed mainly to the Low feeding phase during 5 - 8 weeks and to the second High phase of feeding during 9 - 12 weeks. Thus extreme (Low and High) levels of feeding sharpened the difference in rectal temperature of the Cameroon and the C2 crosses. Females had higher rectal temperature than males with significant differences occurring during the period of conditioning and during the Low phase of feeding (5 - 8 weeks)

The Cameroon had higher values of rectal temperature measured at 20⁰⁰ hrs than the C2 crosses. A significant difference occurred during 5 - 8 weeks. Although females had higher rectal temperature than males at this time, a significant difference occurred during 5 - 8 weeks.

Thus differences in rectal temperature measured at 12⁰⁰ hrs and at 20⁰⁰ hrs between the Cameroon and the C2 crosses on one hand and the males and the females on the other were widened mainly as a result of the Low phase of feeding (5 - 8 weeks) during which a considerable amount of wheat straw was consumed, and to some extent as a result of the second High phase of feeding (9 - 12 weeks) characterised by increased intake of concentrated feed.

Breathing rate: The C2 crosses had higher breathing rate per minute than the Cameroon. The difference was significant during the period of conditioning, during 5 - 8 weeks and during 9 - 12 weeks. Females had higher breathing rate than the males with significant differences occurring during 5 - 8 weeks and during 9 - 12 weeks. The effect of genotype and sex on breathing rate per minute at 20⁰⁰ hrs was not significant. Thus measurement of breathing rate was only relevant at 12⁰⁰ hrs in this case and the difference in breathing rate per minute measured at 12⁰⁰ hrs between the Cameroon and the C2 crosses on one hand and the males and the females on the other were widened as a result of both the Low (5 - 8 weeks) and the second High (9 - 12 weeks) phases of

feeding during which a considerable amount of wheat straw and concentrated feed was consumed, respectively.

Carcass performance: In absolute terms, the C2 had heavier weight of carcass parts than the Cameroon and males more than the females.

The males produced more than the females in terms of total weight of muscle, fat and bones.

Relative weight of fat to weight of carcass part from which it was dissected generally showed more fat deposition in the Cameroon than in the C2 crosses.

The effect of genotype on carcass quality was limited to pH value of MSM, 24 hours post-mortem for which the Cameroon had a significantly higher value than the C2 crosses.

High ambient temperature has been associated with reduced ADG. Ambient temperatures of around 30°C have been associated with reduced feed intake (STELK, 1987) and more time to reach slaughter weight as a result of reduced ADG (STELK, *ibid.*) and reduced milk yield (MIESCKE, 1977; BURMEISTER, 1988) and live body weight (BURMEISTER, *ibid.*) than at lower ones. Changes in some organs have also been reported for example increased weight of heart and reduced weight of liver (STELK, *ibid.*). Reduced rate of passage has also been reported (FAICHNEY and BARRY, 1986; STEIN, 1991). As a result, digesta content tended to increase (FAICHNEY and BARRY, *ibid.*). It would therefore be assumed that the lambs subjected to the heat treatment in the current work could not attain their ADG potential. There was, however, a positive response to the Low-High component of feeding during the last 8 weeks of the experiment in which the C2 crosses had significantly higher ADG than the Cameroon. Thus the C2 crosses could, more than the Cameroon, exhibit the phenomenon of compensatory growth even at high (31°C/50%RH) ambient temperature during the day and low (15°C/70%RH) at night - similar to what has been demonstrated by many workers since the time of OSBORNE and MENDEL (1916) to date to be due to Low-High feeding.

It has been considered that alternating ambient temperature made to be high at one time and low at another has the same effect as constant temperature calculated as the mean of both levels (GROSSMANN, 1983). As has been observed in the current work, C2 crosses whose rectal temperature was higher than that of the Cameroon during the day tended to compensate by having lower temperature at night and vice versa. It has, however, also been considered that diurnally alternating high ambient temperature can adversely affect feed intake during the hot temperature of the day (SCHAFFT, 1993). Indeed at 31°C/50%RH during the day and 15°C/70%RH at night, the feed intake of the C2 was adversely affected during the first four weeks compared with the Cameroon lambs. Although intake of concentrated feed by the C2 crosses during 1 - 4 weeks may reflect problems of adjustment to high ambient temperature of 31°C/50%RH, HAYDEN *et al.* (1993) viewed a similar period of time (i. e. 34 days) to be the necessary period of adjustment for DMI of steers fed on *ad libitum* and restricted basis. FOOT and TULLOH (1977) considered the first three weeks as a period of acclimatisation after observing that maximal feed intake of realimented Aberdeen-Angus steers was reached within three weeks after which it became steady.

Intake of concentrated feed in the previous two experiments in 1994 and 1995 was observed to last only about 15 - 20 minutes unlike in the case of the heat treatment where this lasted longer and was associated with a rather increased frequency of wheat straw intake. KAISER (1992) reported that the rate of rejection of roughage tended to reduce with high ambient temperatures. MULLER *et al.* (1994c) found that dairy cows reared at ambient temperature of 25.1°C or above and provided with shed spent significantly ($p < 0.05$) more time feeding during the day than the no-shed ones except at night when both groups had increased feeding activity than during the day. No-shade cows, however, tended to have more feedings ($p = 0.08$) during the day than those provided with shade and thus tending to agree with the fact that heat stressed animals will tend to regulate body temperature through reduction of appetite (BIANCA, 1971) and that this will tend to be compensated for by increasing the frequency of feed intake.

The difference in rectal temperature between the Cameroon and the C2 crosses measured at 12⁰⁰ hrs at high ambient temperature of 31°C/50%RH especially during 5 - 8 weeks when the Low phase of feeding was administered highlights the fact that the inherent difference between the two genotypes and between male and female lambs could be narrowed or widened (as in this case) depending on the level of feeding. Although KAISER (1992) associated an ambient temperature of

30°C with rise in rectal temperature independent of level of feeding, such rise in rectal temperature could be further enhanced in combination with extremes of either low or high levels of feeding characterised by very high or low fibre content. The difference in rectal temperature of the Cameroon and the C2 crosses measured at 12⁰⁰ hrs with high ambient temperature of 31°C/50%RH during 9 - 12 weeks when the High phase of feeding was administered shows how this difference could also be widened by high level of feeding, though to a lesser degree, compared with the effect of the Low phase of feeding already mentioned. STEIN (1991) and KAISER (1992) confirmed the effect of high (30°C and 35°C) ambient temperature in combination with a high concentrated feed ration to be associated with a lower reduction in metabolic rate compared with a combination of high ambient temperature and high fibre ration. On its own, high ambient temperature around 30°C has been associated with increased concentrations of pancreatic glucagon while depressing those of thyroxin (FAICHNEY and BARRY, 1986).

The difference in rectal temperature of the Cameroon and the C2 crosses measured at 20⁰⁰ hrs at low ambient temperature of 15°C/70%RH especially during 5 - 8 weeks when the Low phase of feeding was administered highlights the same effect of low feeding on rectal temperature already discussed except that it was this time the Cameroon and not the C2 crosses that recorded a higher value. By design, feed intake was low both during the day and at night during 5 - 8 weeks. According to KAISER (1992) increase in high ambient temperature caused reduction in feed intake especially if done in combination with a high fibre ration than otherwise. Conditions of reduced feed intake would imply increased energy expenditure for thermoregulation especially at night when ambient temperature dropped to 15°C which has been associated with negative N retention (KAISER, 1992). At cold ambient temperature (BIANCA and NÄF, 1977; KENNEDY *et al.*, 1982) there is an increase in heat production. Compared with higher levels of ambient temperature, heat production has been found to be highest at cool ambient temperature of 15°C/60%RH in combination with high fibre ration (KAISER, *ibid.*). Low ambient temperature has also been associated with increased thyroid secretion (HOERSCH *et al.*, 1961; HORTON, 1981). For this reason, rectal temperature at 20⁰⁰ hrs was generally found to be higher than that at 12⁰⁰ hrs in the current work. BIANCA and NÄF (*ibid.*) have reported a compensatory rise in body temperature during the cold night accompanied by cardiac acceleration and declining skin temperatures. In the current work, the C2 crosses recorded lower rectal temperature at 20⁰⁰ hrs than at 12⁰⁰ hrs during 5 - 8 weeks when intake of concentrated feed was restricted to 1.5 times above maintenance level.

It is interesting to note that the wide difference in rectal temperature between the Cameroon and the C2 crosses measured at 12⁰⁰ hrs with high ambient temperature of 31°C/50%RH and at 20⁰⁰ hrs with low ambient temperature of 15°C/70%RH during 5 - 8 weeks when the Low phase of feeding was administered has also been reflected between the males and the females with the males always recording a lower value. Rectal temperature of the Cameroon that was higher than that of the C2 crosses at 12⁰⁰ hrs rose to higher than that of the latter at 20⁰⁰ hrs. Thus rectal temperature of the two genotypes was compensated for between day and night unlike that between males and females which was not.

Suitable rearing of C2 crossbred lambs in general and of female lambs in particular at high ambient temperature of 31°C/50%RH would ideally demand a higher level of feeding than was administered here for the sake of reducing rectal temperature. PANT *et al.* (1985) found drastic changes in ambient temperature during the day with strong influence on the physiological reaction of the animals.

Although the C2 crosses recorded higher breathing rate per minute than the Cameroon at 12⁰⁰ hrs with high (31°C/50%RH) ambient temperature, and the females higher than the males under the same conditions, significant differences during the Low (5 - 8 weeks) and High (9 - 12 weeks) phases of feeding show that as with rectal temperature, these differences in breathing rate per minute were highly influenced by the level of feeding. High ambient temperature was found to increase not only rectal temperature and evaporative water loss but respiration rate as well (BUNTING *et al.*, 1992). KAISER (1992) found that raising ambient temperature from 15°C/60%RH to 35°C/60%RH had the effect of causing higher rises in breathing rate per minute and in body temperature when administered in combination with high fibre ration than with high concentrated feed ration. High respiration rate at 32°C ambient temperature has been associated with decreased levels of thyroxin (T₄) and triiodothyronine (T₃) according to PEARSON and ARCHIBALD (1990) and MATHERS *et al.* (1989). High ambient temperature *per se* has also the effect of raising breathing rate per minute. BIANCA and NÄF (1977) associated the change from morning temperature to

afternoon temperature with a 3-fold increase ($p < 0.001$) in breathing rate. Variation based on coat colour (black and white) was more a feature of goats than sheep. In general, body temperature and pulse rate are known to record lower levels during the early hours of the morning and to reach a peak in the later part of the afternoon (PATCHELL, 1954; see also MULLER *et al.*, 1994b).

At 20°C/80%RH, 20°C/60%RH and 25°C/80%RH STEIN (*ibid.*), recorded about 3.5 times increase in breathing rate of adult wethers from a level of 14.1 - 15.2 per minute to about 50 per minute at 30°C/60%RH. FAICHNEY and BARRY (1986) could not associate a 4-fold increase in breathing rate at about 30°C ambient temperature with any significant rise in rectal temperature of sheep. However for lactating dairy cattle a level of ambient temperature of 28°C or above is without any doubt already associated with stress conditions (KLEIN, 1984; RODRIQUEZ *et al.*, 1985).

In excited animals breathing rate may show a distorted picture (HALES and WEBSTER, 1967). A reflection of this was observed in the current work for breathing rate measured at 20⁰⁰ hrs with low (15°C/70%RH) ambient temperature towards the end of the experiment.

The C2 crosses produced bigger carcasses even at high (31°C/50%RH) ambient temperature during the day and low (15°C/70%RH) at night. Relative weight of carcass part to weight of Right Half and weight of muscle and fat to carcass part from which it was dissected showed some variation largely due to genotype and sex and there is nothing to suggest that animals reacted any more different following the heat treatment than they would otherwise have reacted. The Cameroon tended to deposit more fat than the C2 crosses in relative terms.

Almost all the literature referred to above relate to experiments in which animals were exposed to a given constant ambient temperature over a given period of time i. e. not following an alternating daily rhythm. It would, nevertheless, appear that an alternating ambient temperature of 31°C/50%RH during the day and 15°C/70%RH at night would not constitute any constraint, in absolute terms, to rearing of crossbred lambs.

6.4 Pattern of deposition of kidney and mesenteric fat of slaughtered lambs following exposure to different feeding levels under stall ambient temperature conditions (1995) and to high ambient temperature during the day with alternating feeding levels (1996)

With the element of Low feeding in both the High-Low and Low-High feeding treatments, the effect of treatment on the relative amount of total, kidney and mesenteric fat deposited failed to be significant in 1995 although that of kidney fat tended to be higher and that of mesenteric fat lower in the former treatment in which compensatory growth occurred. Relative deposition of kidney fat was significantly higher in the Cameroon than in both the C1 and C2 crosses. Relative deposition of mesenteric fat was significantly higher in both the Cameroon and the C2 crosses than in the C1 crosses.

With High-Low-High feeding in the heat treatment (31°C/50%RH during the day and 15°C/70%RH at night) in 1996, total fat, kidney and mesenteric fat deposited in relative terms was significantly higher for the Cameroon than for the C2 crosses and this shows a similar trend as for the previous experiment in 1995. However, absence of any significant differences between males and females shows an unusual departure from the trend observed during the previous experiment for the same traits. In fact, following the heat treatment, the amount of mesenteric fat deposited in relative terms was higher in the males than in the females although not significantly different. Thus the heat treatment reversed the trend in the deposition of mesenteric fat between males and females unlike the case in the previous experiment at stall ambient temperature. The Cameroon and the male animals form the category of animals that recorded lower rectal temperature at 12⁰⁰ hrs and consequently lower breathing rate compared with the C2 crosses and the female lambs. Males in the heat treatment also consumed *significantly* more concentrated feed, DM and total energy than the females. Internal fat deposition and more especially deposition of mesenteric fat would therefore appear to have implications for thermoregulation. Since the deposition or mobilisation of any sizeable reserves of fat would require a considerably long period of time, such implications for thermoregulation could therefore only be expected to be long-term in nature.

HAYDEN *et al.* (1993) found that a 25% decrease ($p < 0.05$) in kidney, pelvic and heart fat depot was associated with restriction followed by realimentation. MARAIS *et al.* (1991) further found that the fat content of ewe lambs expressed as percentage of live weight was higher than that of ram

lambs. The difference in the pattern of fat deposition between males and females should explain to a large extent the findings of other workers (see ALLDEN, 1968; CAMPBELL, 1988; ABEBE, 1996) regarding the degree to which males would tend to be less tolerant to feed stress than females.

ZIEGLER (1984) associated increased heat tolerance in dairy cattle not only with advanced chronological and reproductive age, but increased fat deposition as well. It is not clear in the current work, exactly why lower rectal temperature and breathing rate during the heat of the day at 31°C/50%RH should be associated with increased deposition of kidney and mesenteric fat observed in the slaughtered Cameroon and male lambs. Hales (Division of Animal Production Research Report, 1978 - 79) mentions that under moderate heat stress i. e. at 40°C ambient temperature, cardiac output in sheep was not increased but that a marked redistribution of blood was effected that resulted in increased flow to tissues of the skin and the respiratory muscle at the expense of flow to the non-respiratory muscle and abdominal organs. It would therefore appear that the increased deposition of fat in the kidney and the intestines is favoured at high ambient temperature so that it does not interfere with thermoregulation in the respiratory organs and the subcutaneous region. This may constitute, at least to some extent, the mechanism of thermoregulation through homeorrheris mentioned by other workers (see ZIEGLER, 1984; SCHAFFT, 1993) and whose effects take place over a long period of time.

6.5 Limitations related to experimental conditions

The relevance of the results of the experiments for tropical conditions is only possible if limitations of experimentation are considered. Crossbreeding Cameroon hair sheep with German mutton and milk breeds to produce C1 and C2 in Berlin and the assessment of their productivity is an important initial step in any effort to promote rearing in the Tropics. However, station research conducted in Dahlem, Berlin, is of limited application where no follow up field research work is done under tropical conditions.

Confinement was necessary to obtain exact data especially relating to feed and water consumption. Confinement, however, excludes the complex effects of direct (radiation, conduction and convection, wind, precipitation and atmospheric pressure) and indirect climatic factors as well as the natural behaviour of animals under variable conditions of climate.

The danger of eroding local genetic resources if no deliberate attempt is made by governments, organisations and individuals concerned, to conserve them - becomes imminent. But considering the drought prone parts of the Tropics where proceeds from the crop production sector are used to purchase more animals whose sale increases in drought years and market peaks during the year, increasing the efficiency of production by rearing crossbred animals produced by mating between exotic animals selected for high performance and local animals adapted to the local environment, is inherently a means to conserve local animal genetic resources.

7 Summary

The purpose of the experiments was to assess the pre- and post-weaning productive performance of Cameroon and crossbred (C1 and C2) lambs at stall ambient temperature and at alternating ambient temperature in the climate chamber. During post-weaning growth, the effect of different feeding levels on growth was assessed at stall ambient temperature and in the climate chamber, both the growth performance and physiological reaction at high (31⁰C/50%RH) ambient temperature during the day and low (15⁰ C/70%RH) at night were assessed between the Cameroon lambs and crossbred lambs. In addition to this, the milk yield performance of the Cameroon and C1 ewes was measured and compared using the suckling method.

The crossbred lambs were obtained by crossing between Cameroon sheep and German breeds of sheep (i. e. Texel, Blauköpfiges Fleischschaf, Rauwolliges Pommersches Landschaf, Coburger Fuchsschaf, Braunes Bergschaf, Merino Landschaf, Weißes Ostfriesisches Milchscharf and Braunes Ostfriesisches Milchscharf). The following categories of animals were used in the pre-weaning growth experiment: 67 (9 Cameroon, 31 C1, 27 C2) suckling Cameroon and crossbred male and female lambs in 1994 and 60 (11 Cameroon, 21 C1 and 28 C2) suckling Cameroon and crossbred male and female lambs in 1995. The following categories of animals were used in the post-weaning growth experiments: 30 (10 Cameroon, 10 C1 and 10 C2) weaned male and female lambs in 1995 and 10 (5 Cameroon and 5 C2) weaned male and female lambs reared at 31⁰C/50%RH vs. 15⁰C/70%RH in 1996. For the milk yield performance experiment, the following genotypes were used in 1995: 17 (8 Cameroon and 9 C1) ewes.

Numerically, about 46% of the C1 crossbred lambs were produced by crossbreeding between the Cameroon and the Texel; and 47% of the C2 crossbred lambs were produced by breeding the C1 (Cameroon x Weißes Ostfriesisches Milchscharf) with another C1 (Cameroon x Braunes Ostfriesisches Milchscharf).

Parameters used included live body weight, milk yield, feed intake, water intake, rectal temperature, breathing rate and carcass evaluation.

All experiments were conducted at the Animal Research Station of the Faculty of Agriculture and Horticulture of the Humboldt University Berlin at Dahlem, Berlin.

The results of the experiments can be summarised as follows:

7.1 Comparative pre-weaning growth performance of lambs of different genotypes

1. Recorded birth weight ($p \leq 0.001$) and estimated Average Daily Gain from birth to 90 days of age ($p \leq 0.001$) of the C1 and C2 crossbred lambs was significantly higher than that of the Cameroon lambs.
2. Recorded birth weight of the C1 crossbred lambs was significantly ($p \leq 0.001$) higher than that of the C2 crossbred lambs although the estimated pre-weaning Average Daily Gain of the latter from birth to 90 days of age was significantly ($p \leq 0.05$) higher.
3. Estimated Average Daily Gain remained constant for the Cameroon lambs from 0 - 30, 30 - 60 and 60 - 90 days of age. For the C1 and C2 lambs, ADG showed highest values from 0 - 30 days of age and lower values later.

7.2 Milk yield performance of Cameroon and C1 ewes using the suckling method

1. The milk yield performance of the C1 ewes was highly significantly ($p \leq 0.001$) higher than that of the Cameroon ewes.
2. The milk yield performance of the C1 ewes was highest in early lactation but declined gradually with advance in the stage of lactation. Contrary to this, the performance of the Cameroon fell sharply after the third week of lactation.

7.3 Comparative post-weaning growth performance of lambs of different genotypes

7.3.1 Influence of different feeding levels on performance

1. A significant ($p \leq 0.05$) difference in live body weight of lambs subjected to High-Low and Low-High feeding only occurred during the 12th week in favour of the latter treatment. The end-weight of the C1 and C2 crossbred lambs was significantly ($p \leq 0.001$) higher than that of the Cameroon lambs. Although the difference between the C1 and C2 crossbred lambs was not significant ($p < 0.05$), the latter had heavier end-weight than the former.
2. Average daily gain was significantly higher ($p \leq 0.001$) for the Low-High feeding treatment than for the High-Low over the whole experimental period. The C1 and C2 crossbred lambs exhibited significantly ($p \leq 0.001$) higher ADG than the Cameroon lambs over the whole experimental period. The difference between the C1 and C2 crossbred lambs was not significant although the former had higher gain than the latter. During the first six (1 - 6) weeks of the experiment, the C2 achieved higher ADG than the C1 although the difference between them was not significant. However, the C1 achieved significantly ($p \leq 0.01$) higher ADG than the C2 during the last six (7 - 12) weeks of the experiment. Average daily gain seen on weekly basis showed a completely different pattern of reaction attributable to treatment.
3. Intake of metabolisable energy over the whole experimental period did not differ significantly between High-Low and Low-High feeding. Intake of energy above maintenance level was, however, significantly higher for the Low-High feeding treatment than for the High-Low one. This is explained by the significant ($p \leq 0.001$) difference during the High phase of feeding (7 - 12 weeks) of the Low-High feeding treatment. Intake of energy above maintenance level did not differ significantly between the Cameroon, C1 and C2 crossbred lambs. The Cameroon, however, recorded the highest value, followed by the C2 crossbred lambs and lastly the C1 crossbred lambs.
4. Intake of wheat straw by lambs subjected to High-Low and Low-High feeding was not significantly different over the whole experimental period. For each treatment, significant intake of wheat straw was associated by the Low phase of feeding. The difference between the three genotypes was significant in the order given: The C1 and C2 crossbred lambs consumed significantly more ($p \leq 0.001$) than the Cameroon lambs due to heavier live weight but the difference between the C1 and C2 crossbred lambs was not significant although the latter consumed more. Higher relative intake of wheat straw (as % of DM intake) by the C1 and C2 crossbred lambs compared with that of the Cameroon was associated with the High phase of feeding.

7.3.2 Reaction to high ambient temperature during the day and of alternating feeding levels

1. There was no significant difference in ADG between the Cameroon and C2 crossbred lambs over the whole experimental period even if the latter recorded a higher value. The C2 crossbred lambs, however, recorded significantly ($p \leq 0.05$) higher ADG than the Cameroon lambs during the second High phase of feeding (9 - 12 weeks). Male lambs also recorded significantly ($p \leq 0.05$) higher ADG than female ones during the second High phase of feeding (9 - 12 weeks) and over the whole experimental period.
2. Intake of metabolisable energy ($p \leq 0.01$) and of concentrated feed ($p \leq 0.05$) was significantly higher for the C2 crossbred lambs than for the Cameroon lambs because of heavier live weight and significantly ($p \leq 0.01$) higher for the males than for the females over the whole experimental period. However, intake of energy above of maintenance level was significantly ($p \leq 0.01$) higher for the Cameroon lambs than for the C2 crossbred lambs during the first High phase of feeding (1 - 4 weeks) as well as over the whole experimental period ($p \leq 0.05$). Intake of energy above of maintenance level was significantly ($p \leq 0.05$) higher for the males than for the females during the second High phase of feeding (9 - 12 weeks).
3. Intake of wheat straw was significantly ($p \leq 0.05$) higher for the C2 crossbred lambs than for the Cameroon lambs during the first High phase of feeding (1 - 4 weeks).

4. High ambient temperature during the day and High-Low-High feeding could not be seen, in physiological terms, to constitute a limiting factor in the rearing of pure Cameroon and C2 crossbred lambs.
5. Irrespective of genotype, rectal temperature measured at 12⁰⁰ hrs with 31⁰C/50%RH ambient temperature was lower than that measured at 20⁰⁰ hrs with 15⁰C/70%RH ambient temperature except during 5 - 8 weeks in the case of the C2 crosses. Rectal temperature and breathing rate per minute recorded in the females was always higher than that recorded in the males. Lower rectal temperature recorded in the males than in the females has been associated with significant intake of energy (see above). Breathing rate per minute recorded in the C2 crossbred lambs was for the most part higher than that recorded in the Cameroon. Compared with the first High phase of feeding (1 – 4 weeks), the Low phase of feeding (5 - 8 weeks) followed by the second High phase of feeding (9 - 12 weeks) increased the significant difference in rectal temperature measured at 12⁰⁰ hrs with 31⁰C/50%RH ambient temperature - between the Cameroon lambs and the C2 crossbred lambs and between male and female lambs. It also increased the significant difference in rectal temperature measured at 20⁰⁰ hrs with 15⁰C/70%RH ambient temperature between the Cameroon lambs and the C2 crossbred lambs and between male and female lambs.
6. Significant differences in rectal temperature between the Cameroon lambs and the C2 crossbred lambs measured at 12⁰⁰ hrs with 31⁰C/50%RH ambient temperature and at 20⁰⁰ hrs with 15⁰C/70%RH ambient temperature were compensated for: lower rectal temperature recorded in the Cameroon lambs and higher recorded in the C2 crossbred lambs at 12⁰⁰ hrs with 31⁰C/50% than at 20⁰⁰ hrs with 15⁰C/70%RH ambient temperature, respectively. However, significant differences in rectal temperature measured at 12⁰⁰ hrs with 31⁰C/50%RH ambient temperature and at 20⁰⁰ hrs with 15⁰C/70%RH ambient temperature between male and female lambs were not compensated for.
7. Compared with the first High phase of feeding (1 – 4 weeks), the Low phase of feeding (5 - 8 weeks) increased the significant difference in breathing rate per minute measured at 12⁰⁰ hrs with 31⁰C/50%RH ambient temperature, between the Cameroon lambs and the C2 crossbred lambs. Again compared with the first High phase of feeding (1 – 4 weeks), both the Low phase of feeding (5 - 8 weeks) and the second High phase of feeding (9 - 12 weeks) increased the significant difference in breathing rate per minute between males and females.

7.4 Carcass evaluation

7.4.1 Influence of different feeding levels on performance

1. Significant increase in ADG as a result of Low-High feeding was due to significant increase in weight of the digestive organs. Low-High feeding also resulted in slight but not significant increase in the weight of the carcass and muscle, fat (except middle) and bones (except for foreleg, middle and neck) of the seven selected valuable parts.
2. The C2 crossbred lambs produced a much heavier Right Half than either the C1 crossbred lambs or the Cameroon. In terms of the relative weight of muscle to carcass part, the C1 and C2 crosses achieved significantly higher values for most parts (foreleg, back, and hindleg) than did the Cameroon. For breast and neck, relative weight of the C2 was significantly higher than that of both the Cameroon and C1 lambs.
3. The weight of the coat of the crossbred lambs was significantly ($p \leq 0.001$) heavier than that of the Cameroon lambs. The weight of the coat was not significantly different between the C1 and the C2 but that of the former was slightly heavier.
4. The effect of treatment on the relative weight of total fat, kidney and mesenteric fat was not significant. However, the effect of genotype ($p \leq 0.05$) and sex ($p \leq 0.01$) on the same was significant. The Cameroon lambs had significantly higher values than both the C1 and C2 crossbred lambs. The difference between the C1 and C2 crossbred lambs failed to be significant at $p \leq 0.05$ although the latter had higher values than the former. Female lambs had significantly higher values than male lambs.

7.4.2 Reaction to high ambient temperature during the day and of alternating feeding levels

1. The C2 recorded significantly higher carcass values than the Cameroon lambs for almost all traits. Relative weight of muscle to carcass part of the C2 was highly significantly ($p \leq 0.001$) for hindleg and thinning. Thus compared to the influence of different feeding levels under stall ambient temperature conditions mentioned above, high ambient temperature affected the C2 lambs by limiting the growth of muscle of most valuable carcass parts (except the in the case of hindleg and neck) when compared with the Cameroon lambs in both cases.
2. At an ambient temperature of 31°C/50%RH during the day and 15°C/70%RH at night, the Cameroon lambs recorded a significantly higher value for relative weight of total ($p \leq 0.01$), kidney ($p \leq 0.001$) and mesenteric ($p \leq 0.001$) fat than the C2 crossbred lambs. A reverse trend in deposition of relative weight of mesenteric fat was observed compared to the trend in the previous experiment such that the males gained more than the females and although the difference was not significant in relative terms, it was significant ($p \leq 0.05$) in absolute terms. The Cameroon and the males form the category of animals that recorded significantly lower rectal temperature and breathing rate during the day. Lower rectal temperature and breathing rate was therefore associated with increased deposition of mesenteric fat and this fact may constitute a mechanism of thermoregulation following long periods of exposure to high ambient temperature.

Bibliography

- 1 ABEBE, G.: Studies on performance potential of Somali goats and their crosses with Anglo-Nubian: A contribution to breed documentation and evaluation. Dissertation. Humboldt-University Berlin, Faculty of Agriculture and Horticulture, Institute for Applied Animal Sciences, 1996
- 2 ADEMOSUN, A. A., BENYI, K., CHIBOKA, O. and C. M. MUNYABUNTU: Review of hair sheep studies in Southwestern Nigeria. Hrsg.: FRITZHUGH, H. A. and G. E. BRADFORD: Hair sheep of Western Africa and the Americas: A Genetic Resource for the Tropics. Boulder, Colorado, USA, Western Press, 1983 S.219 - 226,
- 3 ALLAIN, D.: Biology of fibre growth and shedding. Agriculture: Alternative animals for fibre production, Commission of the European Communities Report. 1993 EUR 14808 EN.
- 4 ALLAIN, D., R. G. THEBAULT, J. ROUGEOT and L. MARTINET: Biology of fibre growth in mammals producing fine fibre and fur in relation to control by day length: relationship between other seasonal functions. Hrsg.: J. P. LAKER and D. ALLAIN: Hormonal control of fibre growth and shedding, European Fine Fibre Network. No. 2 1994
- 5 ALLDEN, W. G.: Undernutrition of the Merino Sheep and its sequelae. III. The effect of lifetime productivity of growth restrictions imposed at two stages of early post-natal life in a Mediterranean environment. Aust. J. Agric. Res.. Band 19. 1968, S.981 - 996,
- 6 ALLDEN, W. G.: Undernutrition of the Merino Sheep and its sequelae. V. The influence of severe growth restriction during early post-natal life on reproduction and growth in later life. Aust. J. Agric. Res.. Band Vol. 30. 1979, S.939 - 948,
- 7 ANONYMOUS: Kamerunschafe: Rassenbeschreibung / Zuchtziel. Deutsche Schafzucht. Band 14. 1992,
- 8 ARC: The nutrient requirement of nutrient livestock. Commonwealth Agricultural Bureaux, Farnham Royal, England. 1980 S.73 - 119,
- 9 ARMBRUSTER, T. and K.J. PETERS: Traditional sheep and goat production in southern Côte d'Ivoire. Small Ruminant Research. 1993, 11, Elsevier Science Publishers B. V., 1993 S.289 - 304,
- 10 BAILEY, C. B.: Effect of environmental temperature on feed digestion, water metabolism, body temperature, and certain blood characteristics of sheep. Can. J. Anim. Sci.. Band 44. 1964, S.68 - 75,
- 11 BEAKLEY, W. R. and J. D. FINDLAY: The effect of environmental temperature and humidity on the rectal temperature of calves. J. Agric. Sci., Camb.. Band 45. 1955, S.339 - 352,
- 12 BEHRENS, H., DOEHNER, H., SCHEELJE, R. and R. WASSMUTH: Lehrbuch der Schafzucht. 4. Auflage Hamburg und Berlin, Verlag Paul Parey, 1976
- 13 BERGER, Y. M.: Djallonké hair sheep in Ivory Coast. Hrsg.: FRITZHUGH, H. A. and G. E. BRADFORD: Hair sheep of Western Africa and the Americas: A Genetic Resource for the Tropics. A Winrock International Study. Boulder, Colorado, USA, Western Press, 1983 S.227 - 240,
- 14 BIANCA, W.: Reaktionen des Rindes auf Kälte und Wärme. Züchtungskunde. 1959, 31, S.476 - 489,
- 15 BIANCA, W.: Haustier und Klima. Schweizer Archiv für Tierheilkunde. 1964, S.535 - 558,
- 16 BIANCA, W.: Neuzeitliche Ergebnisse und Aufgaben der Bioklimatologie bei Haustieren. Der Tierzüchter. 1968, 12, S.438 - 442,
- 17 BIANCA, W.: Die Anpassung des Haustieres an seine klimatische Umgebung. Schweizer landwirtschaftl. Forschung. 1971, 10, S.155 - 204,

- 18 BIANCA, W.: The significance of meteorology in animal production. *Int. J. Biometeorology*. Band 20. 1976, 2, S.139 - 156,
- 19 BIANCA, W.: Temperaturregulation durch Verhaltensweise bei Haustieren. *Der Tierzüchter*. 1977, 3, S.109 - 113,
- 20 BIANCA, W. and NÄF F: Responses of cattle to the combined exposure of, to diurnal temperature rhythm (-5 to 25°C) and to simulated-high altitude (4 000m). *Int. J. Biometeorology*. Band 23. 1977, 4, S.299 - 310,
- 21 BLAXTER, K. L. and N. McC. GRAHAM: Environmental temperature, energy metabolism and heat regulation in sheep. III. The metabolism and thermal exchanges of sheep with fleeces. *J. Agric. Sci., Camb.*. Band 52. 1959, S.41 - 49,
- 22 BLAXTER, K. L. and F. W. WAINMAN: Environmental temperature and the energy metabolism and heat emission of steers. *J. Agric. Sci.*. Band 56. 1961, S.81- 90,
- 23 BLAXTER, K. L. and A. W. BOYNE: Fasting and maintenance metabolism of sheep. *J. Agric. Sci., Camb.*. Band 99. 1982, S.611 - 620,
- 24 BLAXTER, K. L., V. R. FOWLER and J. C. GILL: A study of the growth of sheep to maturity. *J. Agric. Sci., Camb.*. Band 98. 1982, S.405 - 420,
- 25 BLIGH, J.: The receptors concerned in thermal stimulus to panting in sheep. *J. Physiol.*. Band 146. 1959, S.142 - 151,
- 26 BRADFORD, G. E.: The role of maternal effects in animal breeding: VII. Maternal effects in sheep. *J. Anim. Sci.*. Band 35. 1972, 5, S.1324 - 1334,
- 27 BRADFORD, G. E.: A note on characteristics of hair sheep in Senegal. Hrsg.: FRITZHUGH, H. A. and G. E. BRADFORD: Hair sheep of Western Africa and the Americas: A Genetic Resource for the Tropics. A Winrock International Study. Boulder, Colorado, USA, Western Press, 1983 S.241 - 243,
- 28 BRADFORD, G. E. and H. A. FRITZHUGH: Hair sheep: A general description. Hrsg.: FRITZHUGH, H. A. and G. E. BRADFORD: Hair sheep of Western Africa and the Americas: A Genetic Resource for the Tropics. A Winrock International Study. Boulder, Colorado, USA, Western Press, 1983 S.3 - 22,
- 29 BRUCHEM, van, J., A. KAMALZADEH, C. P. LEFFERING, M. J. N. LOS, J. BAAS and S. TAMMINGA: Compensatory development of growing sheep after prolonged feed quality restriction. Voluntary feed intake and rumen residence time. Wageningen Institute of Animal Sciences (WAS), Agricultural University Wageningen, The Netherlands. 1994
- 30 BULLERDIEK, P.: Appraisal of various management interventions in a sheep production system with high gastrointestinal parasite challenge in a subhumid tropical environment. Dissertation. Institute for Applied Animal Sciences, Department of Animal Breeding in the Tropics and Subtropics, Humboldt-University Berlin, 1996,
- 31 BUNTING, L. D., L. S. STICKER and P. J. WOZNIAK: Effect of ruminal escape protein and fat on nitrogen utilization in lambs exposed to elevated ambient temperature. *J. Anim. Sci.*. Band 70. 1992, S.1518 - 1525,
- 32 BURMEISTER, G-A.: Einfluss periodisch alternierender Umgebungstemperaturen auf Milchleistung und Thermoregulation von Kühen der Rasse Deutsche Schwarzbunte in der ersten Laktation. Dissertation. Freie Universität Berlin, 1988
- 33 BURRIN, D. G., C. L. FERRELL, R. A. BRITTON and M. BAUER: Level of nutrition and visceral organ size and metabolic activity in sheep. *Br. J. Nutr.*. Band 64. 1990, S.439 - 448,
- 34 BUTTLER-HOGG, B. W.: Growth patterns in sheep: changes in the chemical composition of empty body and its constituent parts during weight loss and compensatory growth. *J. Agric. Sci., Camb.*. Band 103. 1984, S.17 - 24,
- 35 BUTTLER-HOGG, B. W.: Fat partitioning and tissue distribution in crossbred ewes following

- different growth paths. *Anim. Prod.*. Band 42. 1986, S.65 - 72,
- 36 CAMPBELL, R. G.: Nutritional constraints to lean tissue accretion in farm animals. *Nutr. Res. Rev.*. Band 1. 1988, S.233 - 253,
- 37 CARNAGIE, A. B., N. M. TULLOH and R. M. SEEBECK: Developmental growth and body weight loss of cattle. V. Changes in the alimentary tract. *Aust. J. Agric. Res.*. Band 20. 1969, S.405 - 415,
- 38 CARSTENS, G. E., D. E. JOHNSON, M. A. ELLENBERGER and J. D. TATUM: Physical and chemical components of the empty body during compensatory growth in beef steers. *J. Agric. Sci., Camb.*. Band 69. 1991, S.3251 - 3264,
- 39 CHOI, Y. J., I. K. HAN, J. H. WOO, H. J. LEE, K. JANG, K. H. MYUNG and Y. S. KIM: Compensatory growth in dairy heifers: The effect of a compensatory growth pattern on growth rate and lactation performance. *J. Dairy Sci.*. Band 80. 1997, 3, S.519 - 524,
- 40 CHRISTOPHERSON, R. J.: Effects of prolonged cold and outdoor winter environment on apparent digestibility in sheep and cattle. *Can. J. Anim. Sci.*. Band 56. 1976, S.201 - 212,
- 41 COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RES. ORG: Div. of Animal Production Research Report. Prog. H. 1978 - 79 S.89 - 100,
- 42 COOMBE, J. B., I. D. WARDROP and D. E. TRIBE: A study of the milk production of the grazing ewe, with emphasis on the experimental technique employed. *J. Agric. Sci., Camb.*. Band 54. 1960, S.353 - 359,
- 43 CUMMINS, K. A.: Effect of dietary Acid Detergent Fibre on responses to high environmental temperature. *J. Dairy Sci.*. Band 75. 1992, S.1465 - 1471,
- 44 DAVIS, A. V. and C. P. MERILAN: Effect of constant environmental temperatures and relative humidities on feed digestion by lactating Holstein cows. *J. Dairy Sci.*. Band 43. 1960, S.871,
- 45 DETTMERS, A.: Performance of hair sheep in Nigeria. Hrsg.: FRITZHUGH, H. A. and G. E. BRADFORD: Hair sheep of Western Africa and the Americas: A Genetic Resource for the Tropics. A Winrock International Study. Boulder, Colorado, USA, Western Press, 1983 S.201 - 218,
- 46 DONEY, J. M., J. N. PEART, W. F. SMITH and F. LOUDA: A consideration of the techniques for estimation of milk yield by suckled sheep and a comparison of estimates obtained by two methods in relation to the effect of breed, level of production and stage of lactation. *J. Agric. Sci., Camb.*. Band 92. 1979, S.123 - 132,
- 47 DREW, K. R., and J. T. REID: Compensatory growth in immature sheep. I. The effects of weight loss and realimentation on the whole body composition. *J. Agric. Sci., Camb.*. Band 85. 1975, S.193 - 204,
- 48 DREW, K. R., and J. T. REID: Compensatory growth in immature sheep. II. Some changes in the physical and chemical composition of sheep half-carcass following feed restriction and realimentation. *J. Agric. Sci., Camb.*. Band 85. 1975, S.205 - 213,
- 49 DREW, K. R., and J. T. REID: Compensatory growth in immature sheep. III. Feed utilization by sheep subjected to feed deprivation followed by realimentation. *J. Agric. Sci., Camb.*. Band 85. 1975, S.215 - 220,
- 50 DRIVER, P. M. and J. M. FORBES: Episodic growth hormone secretion in sheep in relation to time of feeding, spontaneous meals and short term fasting. *J. Physiol.*. Band 317. 1981, S.413 - 424,
- 51 DROUILLARD, J. S., T. J. KLOPFENSTEIN, R. A. BRITTON, M. L. BAUER, S. M. GRAMLICH, T. J. WESTER and C. L. FERRELL: Growth, body composition, and visceral organ mass and metabolism in lambs during and after metabolizable protein or net energy restrictions. *J. Anim. Sci.*. Band 69. 1991, S.3357 - 3375,

- 52 FAICHNEY, G. J. and T. N. BARRY: Effects of mild heat exposure and suppression of prolactin secretion on gastrointestinal tract function and temperature regulation in sheep. *Aust. Biol. Sci.*. Band 39. 1986, S. 85 - 97,
- 53 FERNANDES, A. P. and A. P. DESHMUKH: Feedlot performance of Deccani and crossbred lambs from weaning to six months of age. *Indian Journal of Animal Sciences*. Band 56. 1986, 1, S.156 - 157,
- 54 FISHER, A. V. and H. de BOER: The EAAP standard method of carcass assessment. Carcass measurements and dissection procedures. Report of EAAP Working Group on Carcass Evaluation, in co-operation with the CIHEAM Instituto Agronomico Mediterraneo of Zaragoza and the CEC Directorate General for Agriculture in Brussels. *Livestock Production Science*. Band 38. Elsevier, 1994 S.149 - 159,
- 55 FOOT, J. Z., and N. M. TULLOH: Effects of two paths of live weight change on the efficiency of feed use and on body composition of Angus steers. *J. Agric. Sci., Camb.*. Band 88. 1977, S.135 - 142,
- 56 FOOTE, W. C.: The St. Croix sheep in the United States. Hrsg.: FRITZHUGH, H. A. and G. E. BRADFORD: Hair sheep of Western Africa and the Americas: A Genetic Resource for the Tropics. A Winrock International Study. Boulder, Colorado, USA, Western Press, 1983 S.275 - 287,
- 57 FORBES, J. M.: Metabolic aspects of the regulation of voluntary feed intake and appetite. *Nutr. Res. Rev.*. Band 1. 1988, S.145 - 168,
- 58 GATENBY, R. M., M. DOLOKSARIBU, G. E. BRADFORD, E. ROMJALI, A. BATUBARA and I. MIRZA: Comparison of Sumatra sheep and three haired Cameroon crossbreds. II. Reproductive performance of F1 ewes. *Small Ruminants Research*. Band 25. 1997, 2, Elsevier, S.161 - 167,
- 59 GINGINS, M., H. BICKEL and A. SCHUERCH: Efficiency of energy utilization in undernourished and realimented sheep. *Liv. Prod. Sci.*. Band 7. 1980, S.465 - 471,
- 60 GONZALEZ-REYNA, A., DE ALBA, J. and W. C. FOOTE: Reproduction in Peligüey sheep. Hrsg.: FRITZHUGH, H. A. and G. E. BRADFORD:); Hair sheep of Western Africa and the Americas: A Genetic Resource for the Tropics. A Winrock International Study. Boulder, Colorado, USA, Western Press, 1983 S.75 - 78,
- 61 GOODE, L., YAZWINSKI, T. A., MONCOL, D. J., LINNERUD, A. C., MORGAN, G. W. and D. F. TUGMAN: Research with Barbados Blackbelly sheep in North Carolina. Hrsg.: FRITZHUGH, H. A. and G. E. BRADFORD: Hair sheep of Western Africa and the Americas: A Genetic Resource for the Tropics. A Winrock International Study. Boulder, Colorado, USA, Western Press, 1983 S.257 - 274,
- 62 GRAHAM, N. McC., F. W. WAINMAN, K. L. BLAXTER and D. G. ARMSTRONG: Environmental temperature, energy metabolism and heat regulation in sheep. *J. Agric. Sci., Camb.*. Band 52. 1959, S.13 - 24,
- 63 GRAHAM, McC., and T. W. SEARLE: Growth in sheep. II. Efficiency of energy and nitrogen utilization from birth to 2 years. *J. Agric. Sci., Camb.*. Band 79. 1972, S.383 - 389,
- 645 GRAHAM, McC., and T. W. SEARLE: Studies of weaner sheep during and after a period of weight stasis. I. Energy and nitrogen utilization. *Aust. J. Agric. Res.*. Band 26. 1975, S.343 - 353,
- 65 GROSSMANN, R.: Einfluss diurnal wechselnder und konstanter Temperaturen auf Leistungseigenschaften und Thermoregulation unterschiedlich akklimatisierter zweiflaktierender Rinder im Klimakammerversuch. Dissertation. Freie Universität Berlin, 1983
- 66 HADINOTO, P. B.: Untersuchungen zum kompensatorischen Wachstum bei Mastlämmern. Dissertation. Hohe Landwirtschaftliche Fakultät der Rheinischen Friedrich - Wilhelms-Universität zu Bonn, 1984

- 67 HALES, J. R. S. and M. E. D. WEBSTER: Respiratory function during thermal tachypnoea in sheep. *J. Physiol.*. Band 190. 1967, S.241 - 260,
- 68 HAYDEN, J. M., J. E. WILLIAMS and K. J. COLLIER: Plasma growth hormone, Insulin-Like Growth Factor, insulin, and thyroid hormone association with body protein and fat accretion in steers undergoing compensatory gain after dietary energy restriction. *J. Anim. Sci.*. Band 71. 1993, S.3327 - 3338,
- 69 HAENSCH, G. and G. H. de ANTON: Wörterbuch der Landwirtschaft. München, BLV Verlagsgesellschaft mbH, 1996
- 70 HIPPEN, H.: Mechanismen der Temperaturregulation und Adaptation bei laktierenden Kühen unter Wärmebelastung (feucht-heiss und trocken-heiss). Dissertation. Institut für Tierproduktion der Technischen Universität Berlin, 1979
- 71 HOERSCH, T. M. ; H. E. HENDERSON; E. P. REINEKE and H. A. HENNEMAN: Comparative indexes of thyroid function in sheep. *American Journal of Physiology*. Band 201. 1961, 5, S.819 - 822,
- 72 HOGG, B. W.: Compensatory growth in ruminants. Hrsg.: E. M. Pearson and T. R. Dutson: *Growth Regulation in Farm Animals. Advances in Meat Research*. Band 7. 1991, S.103 - 134,
- 73 HOPKINS, D. L. and N. M. TULLOH: Effects of severe nutritional check in early post-natal life on the subsequent growth of sheep to the age of 12 - 14 months. Changes in body weight, wool and skeletal growth, and effects at the cellular level. *J. Agric. Sci., Camb.*. Band 105. 1985, S.551 - 562,
- 74 HORST, P.: Potential of goats for agricultural development in the tropics. *Mal. Vet. J.*. Band 7. 1981, S.19 - 28,
- 75 HORST, P., and K. J. PETERS: Utilization of natural production potentials in dry regions of the tropics. *Quarterly J. Intern. Agric.* Band 22. 1983, 2, Fankfurt (Main), DLG Verlag, S.130 - 148,
- 76 HORST, P., K. J. PETERS and T. K. MUKHERJEE: Research on the efficiency of crossbreeding in goats in Malaysia for the improvement of reproductive and productive performance. In: *Recent German research on problems of parasitology, animal health and animal breeding in the tropics and subtropics. Selected Reports on DFG-Supported Research. Institute for Scientific Co-operation. Tuebingen, 1984 S.119 - 129,*
- 77 HORTON, G. M. J.: Manipulating energy metabolism in sheep exposed to cold. *American Journal of Vet. Research*. Band 42. 1981, 1, S.146 - 148,
- 78 JOHNSON, H. D., H. H. KIBLER, A. C. RAGSDALE and M. D. SHANKLIN: Effects of various combinations of temperature and humidities on milk production. *J. Dairy Sci.*. Band 43. 1960, S.871,
- 79 JOHNSON, H. D. and A. C. RAGSDALE: The effect of rising environmental temperatures (35 - 95 F) on thyroid 131I release rate of Holstein, Brown Swiss and Jersey heifers. *J. Agric. Sci., Camb.*. Band 54. 1960, S.421 - 426,
- 80 JOSHI, B. C., R. E. McDOWELL and D. P. SADHU: Composition of skin secretions from three Indian breeds of cattle under thermal stress. *J. Dairy Sci.*. Band 51. 1968, 6, S.917 - 920,
- 81 KAISER, D.: Nährstoffverdaulichkeit und Wärmeproduktion beim Wiederkäuer unter Wärmebelastung und bei unterschiedlichem Nährstoffangebot. Dissertation. Fachbereich Internationale Agrarentwicklung, Technische Universität Berlin, 1992
- 82 KEARL, L. C.: Nutrient requirements of ruminants in developing countries. *International Feedstuffs Institute, Utah Agricultural Experiment Station, Utah State University Logan, Utah USA, 1982*
- 83 KEENAN, D. M., W. R. McMANUS and M. FREER: Voluntary intake of feed by mature sheep following restricted feeding. *J. Agric. Sci., Camb.*. Band 74. 1970, S.477 - 485,

- 84 KELLY, R. O., F. A. MARTZ and H. D. JOHNSON: Effect of environmental temperature on ruminal volatile fatty acid levels with controlled feed intake. *J. Dairy Sci.* Band 50. 1967, S.531 - 533,
- 85 KENNEDY, P. M., R. J. CHRISTOPHERSON and L. P. MILLIGAN: The effect of cold exposure of sheep on digestion, rumen turnover time and efficiency of microbial synthesis. *Brit. J. Nutr.* Band 36. 1976, S.231 - 242,
- 86 KENNEDY P. M. and L. P. MILLIGAN: Effects of cold exposure on digestion, microbial synthesis and nitrogen transformations in sheep. *Brit. J. Nutr.* Band 39. 1978, S.105 - 117,
- 87 KENNEDY, P. M., R. J. CHRISTOPHERSON and L. P. MILLIGAN: Effects of cold exposure on feed protein degradation, microbial protein synthesis and transfer of plasma urea to the rumen of sheep. *Brit. J. Nutr.* Band 47. 1982, S.521 - 535,
- 88 KEZIE, K. B.: Auswirkung der Beratung auf die Produktivität und Wirtschaftlichkeit der Kleinwiederkäuerhaltung in Togo. Dissertation. Fachbereich Agrar- und Gartenbauwissenschaften der Humboldt-Universität zu Berlin, Institut für Angewandte Nutztierwissenschaften, 1997
- 89 KIRTON, A. H., A. R. QUARTERMANN, A. E. ULJEE, W. A. CARTER and F. S. PICKERING: Effect of 1 or 2 days' ante-mortem fasting on live weight and carcass losses in lambs. *N. Z. Jl. Agric. Res.* Band 11. 1968, S.891 - 902,
- 90 KIRTON, A. H. and D. L. JOHNSON: Interrelationships between GR and other lamb carcass fatness measurements. *Proceedings of the New Zealand Society of Animal Production.* Band 39. 1979 S.194 - 201,
- 91 KLEIN, H. G. F.: Auswirkungen einer Temperaturbelastung während der Dauer der ersten Laktation auf Leistung und Thermoregulation bei Kühen der Rasse Deutsche Schwarzbunte. Dissertation. Institut für Tierproduktion der Technischen Universität Berlin, 1984
- 92 LEDIN, I.: Compensatory growth and carcass composition in lamb and rabbit. Effect of feed energy concentration, restricted feeding and realimentation. Dissertation, Report 120. Swedish University of Agricultural Sciences, Department of Animal Husbandry, Uppsala, 1983
- 93 LEDIN, I.: Effect of restricted feeding and realimentation on compensatory growth, carcass composition and organ growth in lambs. *Swedish J. Agric. Res.* Band 13. 1983, S.175 - 187,
- 94 LEIGHTON, R. E. and I. W. RUPEL: Effects of fibre content of the diet on milk production and hot weather discomfort in producing dairy cows. *J. Dairy Sci.* Band 39. 1956, S.837,
- 95 LIPPKE, H.: Digestibility and volatile fatty acids in steers and wethers at 21°C and 32°C ambient temperature. *J. Dairy Sci.* Band 58. 1975, S.1860 - 1864,
- 96 LITTLE, D. A., and R. L. SANDLAND: Studies on the distribution of body fat in sheep during continuous growth, and following nutritional restriction and rehabilitation. *Aust. J. Agric. Res.* Band 26. 1975, S.363 - 374,
- 97 LONDON, J. C.: Investigations into the present state of production performance and the role of the Djallonke sheep in small farm holdings in the Asante Region of Ghana. Dissertation. Faculty of International Agricultural Development, Institute of Animal Production, Technical University Berlin, 1993
- 98 MALMFORS, B., J. PHILIPSSON and M. HAILE-MARIAM: Capacity building in Ethiopia for sustainable utilization of animal genetic resources. *IRDCurrents.* 13/14,
- 99 MARAIS, P. G., H. J. van der MERWE and J. E. J. du TOIT: The effect of compensatory growth on feed intake, growth rate, body composition and efficiency of feed utilization in Dorper sheep. *S. Afr. J. Anim. Sci.* Band 21. 1991, 2, S.80 - 88,
- 100 MATHERS, J. C., R. P. BABER and R. F. ARCHIBALD: Intake, digestion and gastro-intestinal

- mean retention time in Asiatic buffaloes and Ayrshire cattle given two contrasting diets and housed at 20°C and 33°C. *J. Agric. Sci., Camb.* Band 113. 1989, S.212 - 222,
- 101 McDOWELL, R. E., E. G. MOODY, P. J. VAN SOEST, R. P. LEHMANN and G. L. FORD: Effect of heat stress on energy and water utilization of lactating cows. *J. Dairy Sci.* Band 52. 1969, 2, S.188 - 194,
- 102 McLEAN, J. A.: The partition of insensible losses of body weight and heat from cattle under various climatic conditions. *J. Physiol.* Band 167. 1963, S.427- 447,
- 103 McMANUS, W. R., J. T. REID and L. E. DONALDSON: Studies of compensatory growth in sheep. *J. Agric. Sci., Camb.* Band 79. 1972, S.1 - 12,
- 104 METZ, T., T. K. MUKHERJEE and P. HORST: Assessment of milking ability in meat goats. Proceedings: The 3rd AAAP Animal Science Congress. Band 1. Seoul / Korea, 1985 S.310-311,
- derall 105: METZ, T.. Hrsg.: Milk production of the Malaysian Katjang and German Fawn x Katjang goats estimated by the kid suckling method: Band Dissertation. Fachbereich Internationale Agrarentwicklung, Technische Universität Berlin, S.1977,
- 106 MIESCKE, B. Einfluss einer Temperaturbelastung auf die Leistung laktierender Kühe Dissertation Fachbereich Internationale Agrarentwicklung, Technische Universität Berlin 1977
- 107 MOHAN, K. D. V. G., C. M. NAIDU and K. K. REDDY Feedlot performance of Mandya and Nellore cross lambs *Indian Journal of Animal Sciences* 55:1985:121087 - 1093
- 108 MULLER, C. J. C., J. A. BOTHA, W. A. COETZER and W. A. SMIT Effects of shade on various parameters of Friesian cows in a Mediterranean climate in South Africa. 2. Physiological responses *Afr. J. Anim. Sci.* 24:1994:256 - 60
- 109 MULLER, C. J. C., J. A. BOTHA and W. A. SMIT Effects of shade on various parameters of Friesian cows in a Mediterranean climate in South Africa. 3. Behaviour *S. Afr. J. Anim. Sci.* 24:1994:261 - 66
- 110 MUMIN, D. M. A. Small ruminants in Somalia and their development Proceedings of the workshop on the improvement of small ruminants in Eastern and Southern Africa Nairobi, Kenya 1986:67 - 69
- 111 NAQVI, S. M. K. and A. KRAE Effect of feed restriction followed by realimentation on growth, physiological responses and blood metabolites of native and crossbred sheep *Indian Journal of Animal Sciences* 61:1991:628 - 631
- 112 NGERE, L. O. Size and growth rate of the West African Dwarf sheep and a new breed, the Nungua Black Head of Ghana *Ghana J. Agric. Sci.* 61:1973:113 - 117
- 113 NGERE, L. O. and G. ABOAGYER Reproductive performance of the West African Dwarf and the Nungua Black Head Sheep of Ghana *Anim. Prod.* 33:1981:249 - 252
- 114 NURSE, G., CUMBERBATCH, N. and P. MCKENZIE Performance of Barbados Blackbelly sheep and their crosses at the Ebini station, Guyana *Fritz Hugh, H. A. and G. E. Bradford Hair sheep of Western Africa and the Americas: A Genetic Resource for the Tropics. A Winrock International Study Boulder, Colorado, USA Western Press* 1983:119 - 123
- 115 OSBORNE, T. B. and L. B. MENDEL Acceleration of growth after retardation *American J. Physiol.* XL:1916
- 116 OWEN, J. B. A study of the lactation and growth of Hill Sheep in their native environment and under lowland conditions *J. Agric. Sci., Camb.* 48:1957:387 - 412
- 117 PANT, K. P., F. de A. V. ARRUDA and E. A. P. de FIGUEIREDO Role of coat colour in body heat regulation among goats and hairy sheep in tropics *Pesq. Agropec. Bras.* 20:1985:6717 - 726

- 118PARK, C. S., G. M. ERICKSON, Y. J. CHOI and G. D. MARX
Effect of compensatory growth on regulation of growth and lactation: Response of dairy heifers to a stair-step growth pattern
*J. Anim. Sci.*6419871751 - 1758
- 119PARK, C. S., M. G. BAIK, W. L. KELLER and W. D. SLANGER
Dietary energy restriction-mediated growth and mammary development in rats
*J. Anim. Sci.*7219942319 - 2324
- 120PASTRANA, R. B., CAMACHO, R. D. and G. E. BRADFORD
African sheep in Colombia
FRITZHUGH, H. A. and G. E. BRADFORD
Hair sheep of Western Africa and the Americas: A Genetic Resource for the Tropics. A Winrock International Study
Boulder, Colorado, USA
Western Press198379 - 84
- 121PATCHELL, M. R.
Direct effects of climate on cattle. III. The diurnal trend in body temperature, respiration rate and pulse rate
*NZ J. Sci. Tech.*361954A93 - 102
- 122PEARSON, R. A. and R. F. ARCHIBALD
Effect of ambient temperature and urea supplementation on the intake and digestion of alkali-treated straw by Brahman cattle and swamp buffaloes
*J. Agric. Sci., Camb.*1141990177 - 186
- 123PEART, J. N., R. A. EDWARDS and E. DONALDSON
The yield and composition of the milk of Finnish Landrace x Blackface ewes. I. Ewes and lambs maintained indoors
*J. Agric. Sci., Camb.*791972303 - 313
- 124PETERS, K. J.
The importance of small ruminants in rural development
28Institute for Scientific Co-operation, Tuebingen1988115 - 125
- 125PETERS, K. J. and C. LAES-FETTBACKA
A comparative study of performance of Egyptian Goat breeds. I. Reproductive and dairy performance
*Arch. Tierz.*381995Dummerstorf93 - 102
- 126PETERS, R. R. and H. A. TUCKER
Prolactin and Growth Hormone response to photoperiod in heifers
*Endocrinology*10319781229 - 234
- 127POULTON, S. G. and W. M. ASHTON
Studies on ewe's milk. V. The effect of high cereal diets on ewes and on the yield of milk constituents
*J. Agric. Sci.*781972203 - 213
- 128REYNOLDS, C. K., H. F. FERRELL and P. J. REYNOLDS
Effects of diet-forage-to-concentrate ratio and intake on energy metabolism in growing beef heifers: Whole body energy and nitrogen balance and visceral heat production
*The Journal of Nutrition*12119915994 - 1003
- 129RODRIGUEZ, L. A., G. MEKONNEN, C. J. WILCOX, F. J. MARTIN and W. A. KRIENKE
Effects of relative humidity, maximum and minimum temperature, pregnancy, and stage of lactation on milk composition and yield
*J. Dairy Sci.*681985973 - 978
- 130RYAN, W. J.
Compensatory growth in cattle and sheep
*Nutrition Abstracts and Reviews (Series B)*601990C.A.B. International653 - 664
- 131SALEM, O. A. I., T. T. EL-GALLAD, S. M. ALLAM, M. M. E. HASSOUNA and M. S. FARGHLY
Effects of periodic feed restriction with subsequent realimentation on performance of Baladi goats
*Small Ruminant Res.*21989AmsterdamElsevier Science Publishers B. V.133 - 141
- 132SANUDO, C., I. SIERRA, M. J. ALCADE, A. ROTA and J. C. OSORIO
Carcass and meat quality of light and medium weight Rasa Aragonesa, Lacaune and German Merino lambs
43rd Annual Meeting of the European Association for Animal Production1992
- 133SAUBIDET, C. L. and L. S. VERDER
Relationship between live weight, age and dry matter intake for beef cattle after different levels of food restriction
*Anim. Prod.*22197661 - 69
- 134SCHAFFT, H.
Einfluss thermischer Klimafaktoren auf Stoffwechsel und Wachstum beim Wiederkäuer
Habilitationsschrift
Fachbereich Agrar- und Gartenbauwissenschaften der Humboldt-Universität zu Berlin1993
- 135SCHANBACHER, B. D. and J. D. CROUSE
Growth and performance of growing-finishing lambs exposed to long or short photoperiods
*Journal of Anim. Sci.*5119804943 - 948

- 136 SCOTT, G. H. and E. G. MOODY Tolerance of dairy cows to high climatic temperatures on low roughage ration *J. Dairy Sci.* 43:1960871 - 872
- 137 SEARLE, T. W., N. McC. GRAHAM and M. O'CALLAGHAN Growth in sheep. I. The chemical composition of the body *J. Agric. Sci.* 79:1972371 - 382
- 138 SEARLE, T. W., N. McC. GRAHAM Studies of weaner sheep during and after a period of weight stasis. II. Body composition *Aust. J. Agric. Res.* 26:1975355 - 361
- 139 SEARLE, T. W., N. McC. GRAHAM and J. B. DONNELLY The effect of plane of nutrition on the body composition of two breeds of weaner sheep fed a high protein diet *J. Agric. Sci.* 98:1982241 - 245
- 140 SHELTON, M. Crossbreeding with the "Barbado" breed for market lamb or wool production in the United States FRITZHUGH, H. A. and G. E. BRADFORD Hair sheep of Western Africa and the Americas: A Genetic Resource for the Tropics. A Winrock International Study Boulder, Colorado, USA Western Press 1983. 293 - 297
- 141 STEIN, M. Einfluss des Wirkungskomplexes Umgebungstemperatur und Luftfeuchte auf Nährstoffverdaulichkeit und Energiebilanz beim Schaf Dissertation Fachbereich Internationale Agrarentwicklung, Technische Universität Berlin 1991
- 142 STELK, A. Mastleistung und Schlachtkörperzusammensetzung unter dem Einfluss einer Wärmebelastung von wachsenden Merinoschafen Dissertation Fachbereich Internationale Agrarentwicklung, Technische Universität Berlin 1987
- 143 THOMSON, E. F., H. BICKEL and A. SCHUERCH Growth performance and metabolic changes in lambs and steers after mild nutritional restriction *J. Agric. Sci.* 98:1982183 - 194
- 144 THORNTON, R. F., R. L. HOOD, P. N. JONES and V. M. RE Compensatory growth in sheep *J. Agric. Res.* 30:1979135 - 151
- 145 TOUKOUROU, Y. Auswirkung unterschiedlicher Fütterungsintensitäten während der laktogenen Aufzuchtphase auf das kompensatorische Wachstum von Ziegenlämmern Dissertation Fachbereich Agrar- und Gartenbauwissenschaften der Humboldt-Universität zu Berlin, Institut für Angewandte Nutztierwissenschaften 1997
- 146 VIMINI, R. J., J. D. KEMP, W. G. MOODY, D. G. ELY and W. P. DEWEESE Effects of maternal nutritional restriction during gestation and maternal frame size on lamb growth and performance. I. Influence on lamb performance and carcass characteristics, II. Influence on skeletal muscle growth and development, III. Influence on histological characteristics of skeletal muscle, IV. Influence on subcutaneous adipocyte development Progress report 279 Kentucky Agric. Exp. Station, USA 1984:29-44
- 147 VISSCHER, A. H. Assessment of carcass quality in live lamb by handling and visual assessment Institute for Animal Production "Shoonoord", Zeist, The Netherlands
- 148 WALI, S. A. and A. M. ASHIR Physiological responses of Awassi sheep to water and feed restrictions *Indian Journal of Animal Sciences* 60:19906690 - 692
- 149 WALLACE, L. R. The growth of lambs before and after birth in relation to the level of nutrition *J. Agric. Sci.* 38:194893 - 153
- 150 WAYMAN, O., H. D. JOHNSON, C. P. MERILAN and I. L. BERRY Effect of ad libitum or force-feeding of two rations on lactating dairy cows subject to temperature stress *J. Dairy Sci.* 45:19621472 - 1478
- 151 WHITTOW, G. C. The significance of the extremities of the ox (*Bos taurus*) in thermoregulation *J. Agric. Sci.* 58:1962109 - 120
- 152 WHITTOW, G. C. and J. D. FINDLAY Oxygen cost of thermal panting *American Journal of Physiology* 214:1968194 - 99
- 153 WILSON, R. T. Sedentary sheep in the Sahel and Niger Delta of Central Mali FRITZHUGH, H. A. and G. E. BRADFORD Hair sheep of Western Africa and the Americas: A Genetic

Resource for the Tropics. A Winrock International StudyBoulder, Colorado, USAWestern Press1983245 - 254

- 154WOLDEGHEBRIEL, A., C. KHAN, C. WILLIAMS, D. VAUGHN, and D. MAXWELLEffects of controlled feed intake on growth, feed efficiency and visceral organ weights of growing pigsTrop. Agric. (Trinidad)7119942157 - 159
- 155WRIGHT, I. A. and A. J. F. RUSSELChanges in the composition of beef cattle during compensatory growthAnim. Prod.521991105 - 113
- 156YOUSEF, M. K., H. H. KIBLER and H. D. JOHNSONThyroid activity and heat production in cattle following sudden ambient temperature changesJ. Anim. Sci.261967142 - 148
- 157ZARAZUA, M. V. and E. G. PADILLAPelibuey sheep in MexicoFRITZHUGH, H. A. and G. E. BRADFORDHair sheep of Western Africa and the Americas: A Genetic Resource for the Tropics. A Winrock International StudyBoulder, Colorado, USAWestern Press198355 - 73
- 158ZIEGLER, H.Adaptation und Energiehaushalt laktierender Kühe bei hohen UmgebungstemperaturenDissertationFachbereich Internationale Agrarentwicklung, Technische Universität Berlin1988

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Lebenslauf

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Eidstattliche Erklärung

Hiermit versichere ich, daß ich die vorliegende Dissertation mit dem Titel "Pre-weaning growth performance of hair x mutton sheep crosses and post-weaning growth and physiological reaction in response to different feeding levels and high ambient temperature" selbständig und ohne unerlaubte Hilfe angefertigt habe. Sie hat bislang weder in Teilen noch als Ganzes einem Promotionsverfahren zugrunde gelegen.

Berlin, den 15.09.2000 Willard Lumoma Bboonko Simukali