STUDIES ON GROWTH RATE, CARCASS QUALITY AND HELMINTH RESISTANCE OF THREE STRAINS OF TANZANIA LOCAL GOATS

BY

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ABSTRACT

This study was conducted on three strains (Kigoma, Dodoma and Mtwara) of Tanzanian local goats with the aim of estimating heritability for pre weaning (birth-4 months), post weaning (4-8 months) and yearling (8-12 months) growth rates. Other heritability parameters estimated were for weight at birth, 4, 8, and 12 months of age and helminth resistance traits i.e. Faecal egg count (FEC) and packed cell volume (PCV). Data accumulated between 1997 and 2000 was used to estimate heritability. The same data set was used to evaluate the effect of sex, birth type, strain, year of birth on growth rate at four, eight and twelve months of age. This formed part I of the study. In part II of the study, the effect of worm burden on growth rate was done only on goats that had available information on PCV and FEC at six and twelve months of age. This study also evaluated the effect of strain on killing out characteristics, carcass quality and composition as well as development of prediction equations/models for carcass weight and carcass tissues. Most of the traits considered were observed to have (0.32-0.39) moderate heritability, with exception of weight at weaning, 8 months, one year of age and PCV, which had high (0.4-0.44) heritability. Strain had a significant influence ($P<0.05$) on growth rate at four, eight and twelve months of age. The Dodoma strain had highest daily gain at four months (40.0g), eight months (37.6g) and twelve months (32.6g) of age compared to that of Kigoma (34.6g, 35.2g, 31.4g) and Mtwara (32.3g, 29.4g, 26.1g), respectively. Sex had a significant influence on growth rate only at four months of age. Male kids had higher daily gain than females. There was a significant effect of worm burden on growth rate at six and twelve months of age. Dodoma strain showed lowest FEC and highest PCV and growth rate. Mtwara strain showed highest level of FEC and the lowest

PCV and growth rate. Kigoma strain was in between the other two strains. Susceptibility to helminth infection measured by FEC and PCV indicated that Dodoma strain did not differ significantly ($P>0.05$) from that of Kigoma strain, and that both of them were more resistant than Mtwara strain. Further more, results indicated a negative correlation between FEC and PCV at both ages. FEC also had a negative relationship with growth rate at six and twelve months of age, whereas PCV showed a positive relationship with growth rate. There were significant differences between strains in dressing percentage (DP), slaughter weight, empty body weight and carcass weight. Dodoma strain had the highest weights followed by Mtwara and Kigoma. Dressing percentage was 49.3% in Dodoma strain, 45.5% in Mtwara strain and 44.8% in Kigoma strain. Strain effects were also observed for edible non-carcass components when expressed as percentage of slaughter weight. Dodoma strain had the highest weight of kidney, head, feet, and gut fat compared to Mtwara and Kigoma. Other edible non-carcass components such as pluck, spleen, liver, and gut were heavier for Dodoma strain than those of others trains albeit the differences were not significant. Carcass composition consisted of 70.3, 69.8, and 68.4% for lean; 17.8, 18.8 and 19.7% for bone; 12.5, 15.5, and 15.5% for fat in Dodoma, Mtwara and Kigoma strains, respectively. Strain effect was also evident in carcass tissue ratios, with Dodoma goats showing better proportions than Mtwara and Kigoma. Strain also had significant effect ($P<0.05$) on carcass joint weights. The Dodoma strain exhibited heaviest weights of ribs, breasts, loin and feet than the other two strains. Heart girth was the best independent variable in predicting carcass weight ($P<0.002$, $R^2 = 82.4\%$). Foreleg joint was the best predictor of lean ($P<0.001$, $R^2 = 92\%$), while rib joint was the best predictor of both carcass bone ($P<0.001$, $R^2 = 87\%$) and fat ($P<0.001$, $R^2= 80\%$). Of the

the three independent variables namely slaughter weight, carcass weight and empty body weight, carcass weight was the best predictor of lean ($P<0.001$, $R^2 = 98\%$) and fat ($P<0.001$, $R^2 = 87\%$), whereas slaughter weight was the best predictor of bone ($P<0.001$, $R^2 = 89\%$). It was generally concluded that of the threes trains, the Dodoma strain was superior to the rest in terms of growth rate, helminth resistance and carcass quality. Selection, bio-molecular techniques and cross breeding could be employed to improve these traits because they have moderate heritability.

DECLARATION

I, JULIUS LUHENDE MALOLE, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and that it has never been submitted for a higher degree in any other University.

Signature...

Date......3/9/2002..

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DEDICATION

This dissertation is dedicated to my beloved wife Zuhura, my daughter Nshoma, my son Luhende and my parents.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF PLATES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
ARC	Agriculture Research Council
BL	Body length
BW	Body weight
DP	Dressing percentage
ELIZA	Enzyme linked immunosorbent assay
ENRECA	Enhancement of Research Capacity
FEC	Faecal egg count
h2	Heritability
HB	Haemoglobin
HG	Heart girth
HR	Height at rump
HW	Height at withers
ILCA	International Livestock Center for Africa
LS means	Least squares means
LFEC	Logarithm transformed faecal egg count
LPCV	Logarithm transformed packed cell volume
MAFF	Ministry of Agriculture, Fisheries and Food
MALD	Ministry of Agriculture and Livestock Development
MoA	Ministry of Agriculture
R2	Coefficient of determination
r	Correlation coefficient
SEA	Small East African

SUA	Sokoine University of Agriculture
US$	United state dollars
Var	Variance
V_P	Phenotypic variance
V_A	Additive genetic variance

CHAPTER ONE

1.0 INTRODUCTION

Tanzania has 11.6 million goats (MoAFS, 2001) of which the indigenous Small East African (SEA) goat is the predominant breed. Recently, a few exotic goat breeds have been introduced mainly by Development Projects (Kusiluka, 1995). The local strains of small ruminants are kept mostly under the traditional sector for meat production. It is estimated that 17% of total meat produced and consumed in Tanzania is contributed by small ruminants (Mtenga and Kidunda, 1986). Other roles of small ruminants include provision of manure as fertilizer to improve crop yield, skin, a little milk and they serve as source of income since they can be easily sold when needs arise. According to Mtenga and Kusiluka (1997) goats in Tanzania provide meat whose value is about US$ 48 million per year. They are also useful in traditional functions such as rituals, festivals and paying of bride price.

The major constraints hindering the productivity of the small ruminant sector in Tanzania are inadequate nutrition, diseases, poor breeding policies and poor management (Njombe, 1993), lack of supportive service viz unavailability of veterinary services and ineffective extension services. However, the Tanzanian local goat is a hardy animal, which thrives well in harsh conditions of semi- arid and arid areas characterized by shortage of forage and water attributed to frequent occurrence of droughts.

The common health problems which have been reported to affect small ruminants in Tanzania are helminthosis, foot rot, pneumonia, orf, coccidiosis and lamb or kid scours (Kusiluka, 1995; Kiango, 1996). It has been estimated that 40 – 60% of small ruminants losses in Tanzania are due to diseases (Mtenga, *et al.*, 1994; Kusiluka, 1995) and of all the diseases, worm infestation is considered to be the most important. Parasitic worm burdens are paramount and cause considerable losses. The clinical manifestations range from death, severe anaemia, diarrhoea, reduced growth rate, feed intake, feed utilization, fertility to lowered productivity (Kassuku and Ngomuo, 1997). Furthermore, certain helminth parasites such as *Taenia saginata* and *Echnococcus granulose* cause zoonotic diseases. The most prevalent helminths in Uganda, Kenya, Tanzania and sub-saharan Africa at large are *Hemonchus contortus, Trichostrongylus colubriformis and Oesophagostomum columbianum*. Of these helminths *Haemonchus contortus* is ranked as the major constraint, whereas other cestodes viz *Taenia ovis* (Metacestodes, cysticercus ovis) cause meagre acceptability of meat and are therefore important causes of organ condemnations in slaughter houses. At Sokoine University of Agriculture, the nematodes that have been identified affecting SEA goats at Magadu Farm are *Haemonchus spp, Oesophagostomum columbianum, Trichostronglus spp, Cooperia spp, Strongyloides spp* and *Trichurius spp, (Kusiluka, 1995; Keyyu, 1998*).

Resistance to diseases is an important aspect in livestock development and is genetically controlled and heritable in cattle, sheep and goats. Thus breeding for resistant animals is feasible. Animals with genetically improved resistance carry fewer worms than susceptible animals and that the worms are less fecund (Nicholas, 1991; Bisset *et al.*, 1996). Some genes (loci) on the major histocompatibility complex (MHC) region of the genome are genetically associated with resistance to nematode infection (Schwaiger *et al.,* 1995). A major gene for resistance to *Ostertagia circumcicta* in sheep has been identified around the MHC (Keyyu, 1998). Generally, Baker (1995) reported that the indigenous breeds of goats in East Africa (SEA) are more resistant than the exotic breeds. Furthermore, significant variation in resistance to gastrointestinal nematodes, as indicated by FEC and PCV, has been reported (Keyyu, 1998) among three strains of SEA goats, with Dodoma and Mtwara strains showing the highest and lowest resistance respectively, and the Kigoma strain being in between. In contrast, Gimbi (2000), observed that the Mtwara and Dodoma strains showed the highest and lowest resistance respectively, and Kigoma strain being in between.

Another important parameter in meat production is growth rate. The rate of growth has an implication in the amount of meat output obtained and the length of the period to reach the target slaughter weight. Growth in kids is an indicator of adaptation and viability and it is expressed as an increase in weight and body size associated with biosythesis of body tissues. It is a gain in weight per unit time. In meat animals, growth is centred on the development of the three main components of the carcass namely lean, bone and fat (Mtenga and Kidunda, 1986; Kamwanja *et al.*, 1990).

Generally, goats in the tropics have lower growth rate compared to temperate breeds when other factors are not limiting (Bradford and Berger, 1988; Mourad, 1993). In preweaners, an average daily gain of 25 – 44g per day for various indigenous tropical goat breeds have been reported (Karua and Banda, 1992) against 150 to 250g/ day for temperate goats (Madsen and Mtenga,1988; Mourad, 1993 and Gebrelul *et al.*, 1994). The daily gain of 44.5g/day has also been reported by Challya (1998) in SEA goats at SUA. Moreover, average daily gain of 54 – 80g per day for large local breeds have been reported (Gebrelul *et al.*, 1994).

Carcass yield and quality is also an aspect of interest in meat production. Body weight is one of the most important predictors of carcass yield and is the determinant of the commercial value of an animal. The carcass of a domestic animal is that portion of the body remaining after the complete removal of the skin, feet, heart, offals (gastrointestinal tract) uro-genital system, respiratory system, liver and spleen (Yeates *et al.,* 1975). According to Lawrie (1979), the carcass is made up of muscular, fatty and bone tissues. The proportions of these tissues largely determine the value of the carcass (Kyomo, 1978). A superior carcass is one which consists of maximum amount of muscle, a minimum of bone and an optimum of fat as desired by consumers (Berg and Butterfield, 1976; Daka, 1987). Mahgoub and Lodge (1994) recommended slaughter of sheep and goats at a lighter weight (at 72 weeks of age), especially when the plane of nutrition is high to avoid too much fat on the carcass. However this criterion can be misleading because in the tropics, animals are raised under low plane of nutrition of natural grasslands; the animal will be too light for slaughter at 72 weeks. On the other hand, Mtenga *et al.* (1994) found that the small ruminants in Tanzania are slaughtered when they are 2-3 (262 – 730 days) years of age. Slaughter weight for SEA goats in Tanzania ranges from 12 – 20 kg (Madubi, 1997); 14 – 41 kg (Mtenga *et al.*, 1994), with an average slaughter weight of about 18 – 20 kg. Thus, great variation in age at slaughter of small ruminants reflects great variation in genetic make up, management, meat quality and preference from these animals (Mtenga *et al.*, 1994). Unfortunately, there is very little information on slaughter weight of small ruminants in the traditional sector. This is because the slaughter weight data for small ruminants is from research stations. Therefore, this is an area, which needs further research.

There is growing evidence which suggests that animal production can be increased by improving local breeds, which are adapted to an area, readily available to a particular locality and already accepted by livestock keepers. However, genetic parameters of local strains of goats are hardly known. That is, genetic parameter estimates are scarce in goats reared under Tanzania conditions, and where such information is available analytical methods tend to be inadequate. The broad objective of this study was to compile, analyse and compare growth rates, carcass quality and helminth resistance of three strains of Tanzania local goats.

Specific objectives of this study were:

1. To evaluate the effect of strain, worm burden, sex, birth type and year of birth on growth rate.
2. To evaluate strain effect on killing out characteristics, carcass quality and composition
3. To develop prediction models for carcass weight using linear body measurements and composition using carcass joints, carcass weight, empty body weight and slaughter weight.
4. To estimate heritability for helminth resistance, growth rate and weights at different ages.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 General over view

Small ruminants are important components of the farming systems in Tanzania. The semi intensive system is probably the major system of small ruminant production in Tanzania because agro pastoral societies are wide spread all over the country. In this system, subsistence is derived mainly from agriculture, thus farmers are mainly engaged in farm activities related to crop production and relatively little time is spent to attend the animals. There is also little veterinary attention and controlled breeding.

The indigenous goats are kept mainly for meat, skin, and manure and to a less extent for milk production. However, the per capita consumption of animal protein is in the order of 11.54 g per day, which is very far below the recommended level of 21g of animal protein per person per day (FAO, 1994).

It has been observed that, human population grows faster than livestock population. The situation in Tanzania is that, the trend of human population growth is higher than that of livestock (FAO, 1994). The human population is about three times that of goats. Assenga (1997) reported that the human population is about 6 times that of small ruminants in Morogoro region. Information on trend of population increase in human, cattle, sheep and goats in Tanzania is shown in Table 1.

Tablel: Trend of population increase in human, cattle, sheep and goats (millions) in Tanzania

Source	Year	Human population	Cattle	Goats	Sheep
Census	1961	9.0	9.6	3.8	2.70
MALD	1978	17.0	12.0	5.5	3.10
FAO	1984	21.2	12.5	6.4	3.34
FAO	1995	25.0	13.6	10.6	3.38
Bureau of Statistics	1998	30.0	15.6	10.7	3.40
MoAFS	2001	35.0	16.4	11.6	3.50

Since the population growth is 3.5% per annum (FAO, 1983), there is a need therefore to increase the pace of small stock population growth and increase productivity of these animals so as to meet the demand for protein for this population.

2.2 Importance of indigenous goats

2.2.1 Adaptation to feeding habits and tropical environment

Indigenous breeds of goats are adapted to a wide range of ecological zones. That is, natural selection and genetic variability seems to have conferred to local goats some adaptive characteristics, which enable them to survive and withstand harsh conditions in semi-arid and arid areas where there is shortage of water and pasture. Their adaptive features enable them to survive, reproduce and produce even in areas affected with most of tick-borne diseases and tsetse flies, the carriers of trypanosomosis (Fedele *et al.*, 1993; Kusiluka, 1995). Also, the inherent characteristics of goats such as resistance to dehydration, preference for browse and wide range of feeding habits enable them to thrive in regions that receive less than 750 mm of rainfall per annum. Further more, Fedele *et al.* (1993) observed that goats have the ability to balance dietary energy and protein caused by environmental variation to nutrition requirements. This behavioral trait of browsing makes it easier for the animal to cope with a comparable amount of toxin from different plant species rather than one single source. Thus, it prevents the animals' detoxification mechanism from being controlled with large dose of one single toxin (Moss, 1991)

2.2.2 Disease resistance

In the tropics small ruminants have a wide range of genetic variability, which enable them to survive under high disease incidences and other harsh environmental conditions. Resistance to a wide range of diseases is also attributed to their ability to utilize different varieties of plants (Reynolds, 1986; Bisset *et al.*, 1996). Indigenous goats are resistant to most of tick-borne diseases, dehydration, nematodes (particularly *Haemonchus contortus),* with exception of some other conditions like Haemorrhagic septicaemia. Indigenous goats are relatively more resistant to trypanosomosis than sheep, but highly susceptible to contagious eczema, pneumonia, gastroenteritis and parasites.

2.2.3 Small body size

Small size of body has made goats to have high prolificacy, short generation interval, low investment costs and easiness with which goat carcasses can be disposed of when storage facilities are lacking (Gamaliely, 2000).

2.3 Production performance of local goats

2.3.1 Growth rate

Growth is defined as an increase in weight and body size associated with biosynthesis of body tissues. Growth can be measured by the actual weight change of the animal at particular period intervals using growth curve and weight per unit time. The rate of growth is one of the most important traits in meat production as it has implications in the amount of meat output obtained and age at target weights viz puberty and slaughter weight. Different growth rates for goats have been reported under field conditions in various parts of Africa. In Uganda, Kiwuwa (1986) reported 55, 56g/day and 38, 45 g/day as pre- and post weaning growth rates of Mubende and SEA goats, respectively. In Kenya, Gathuka (1986) reported growth rates of 110 and 90g/ day for Galla and SEA goats respectively. In Tanzania, Mtenga *et al.* (1984) reported daily gain of 42.1g for pre-weaning growth rate. The rate at which the animal grows is determined by genetic, non-genetic factors and the interaction between them. These factors contribute to the existence of variation in growth rates within breed and between breeds. Existence of breed differences in growth rate enable selection for fast growing breeds for meat production. In this review, genetic variability among and within breeds especially in indigenous Tanzanian goats with respect to growth performance and disease resistance are considered.

Growth phases are categorised as prenatal and postnatal stages. The postnatal phase being further categorised into pre-weaning and post weaning phases. Pre-weaning growth rate is the period between birth and weaning, during which the kid suckles milk from the dam, and may last from 1 to 5 months depending on management

(Mourad, 1993). The animal is growing at an increasing rate. Weaning is the management practice whereby kids are separated from their dams and fed roughages or solid feeds. This period is characterized by slow growth rate or even loss of weight from the first 7 to 14 days after weaning (Rhind, 1992; Mourad, 1993). Das *et al.* (1989) working on Galla and Blended goats reported average weaning weight of 10.7 kg at four months. Post weaning phase is the period between weaning and target weights such as mating weight, slaughter weight or mature weight. This covers the period in the growth curve where the animals are growing at a decreasing rate (Mourad, 1993). In this phase, growth depends largely on environmental factors mainly availability of feeds in terms of quality and quantity and management (Bradford and Berger, 1988) and genetic factors (Abunie, 1992). The changes in linear body measurements such as body length, heart girth, wither height, width of hind quarters and chest depth are also indicators of growth (Kyomo, 1978; Hassan and Ciroma, 1990). It has been established that goats of different breeds, sex and plane of management grow at different rates. Studying on the East African local goat breeds in Tanzania (Madubi, 1997) reported that, these animals have lower growth rates at any phase compared to imported temperate breeds when other factors are not limiting. However, under tropical conditions where there are harsh environmental conditions, lower growth rates are expected from the exotic breeds compared to local animals (Gebrelul *et al.*, 1994).

As afore- mentioned, there are many factors which influence growth rates in various growth phases (pre- weaning, weaning and post weaning) in goats, and the key factors include genetic (breed) and or breed level and non-genetic factors such as birth type, season of birth, year of birth, sex, nutrition, parity and age of the dam (Malick *et al.*, 1986).

2.3.1.1 Birth weight

Birth weight is a key indicator of growth rate and an economic trait which has positive correlation with kid survival, postnatal performance and mature body size. Kids with low birth weight grow slowly and are more prone to diseases than those which are heavier at birth (Madsen and Mtenga, 1988). There is great variation in birth weight which is attributed to genetic and environmental factors. Madubi (1997), Devendra and Mcleroy, (1982a); Abunie (1992) and Challya (1998) reported mean birth weights of 2.5, 2.2, 1.34 to 2.20 and 1.6 kg for SEA goats, respectively. Challya (1998) working on Small East African goats reported birth weight of 1.6 kg. Pre-weaning growth rate and weaning weight depends on birth weight. Kids with larger weights at birth grow faster and therefore attain higher weaning weight (Djemali *et al.*, 1994).

2.3.1.2 Season of birth

Season of birth has effect on birth weight. Kids born in rainy season tend to have higher body weight at birth than those born in dry season (Malick, *et al.*, 1986). This is due to availability of forages and shrubs for ample browsing in the rain season, but during the dry season where availability of forage is limiting, pregnant does may not have enough energy for maintenance and pregnancy and thus limited nutrients are available for foetal growth (Rhind, 1992). Season of kidding has been shown to have effect on pre-weaning, weaning and post weaning weights in several studies (Nagpal and Chawala, 1995; Wilson and Murayi, 1988; Roy *et al.*, 1989; Banda, 1999). In most studies, kids born in the dry season were inferior in pre-weaning and post weaning weights to kids born in the wet season. This effect is associated with food scarcity and heat stress in dry season, which results in low growth rates.

2.3.1.3 Year effect

There is an association between years of birth and growth rates at different ages. Kyomo (1978) and Nagpal and Chawal (1995) observed significant effect of year of birth on birth weight, pre-weaning and post weaning weights. This effect was due to year-to-year variation in climatic factors (rainfall, temperature and humidity), which influenced forage availability, management and disease conditions (ILCA, 1989).

2.3.1.4 Sex effect

Sex has significant influence on birth weight, pre-weaning and post weaning weights. The differences in growth rate between the sexes is due to differences in the number of muscle cells being higher in male than in female kids. The differences are even more pronounced after weaning due to the additional factor of sex hormones such as testosterones whose potency to promote growth is greater than oestrogen from females (Rhind, 1992). In goats, on average males are superior to females in birth weight by 5 to 15% (Morand –Fehr, 1981). However, it must be understood that superiority of males over females is more pronounced when nutrition and other factors are not limiting during the gestation period (Mtenga *et al.*, 1994).

2.3.1.5 Birth type

It has also been reported that the type of birth has an influence on growth rates in various growth phases. Single born kids are superior to multiples (Kyomo, 1978; Hofs *et al.,* 1984). This is in line with findings by Das and Sendalo (1990) who observed growth rates of 95.4g per day for singles and 80.5g for multiples in meat goats (Malya) in Tanzania. Although there is a tendency for does with twins to give more total milk, but milk available per kid is lower compared to does with single kids. Also maternal environment such as dam nutrition for foetal development during pregnancy could be the main cause for low birth weight (Lebbie and Manzine, 1989; Das and Sendalo, 1990; Gebrelul *et al.*, 1994). This means that, for dams with single kids any nutritional allowance for pregnancy is used by a single foetus whereas in case of multiples it has to be shared among the foetuses. Many reports (e.g. Madsen and Mtenga, 1988; Karua and Banda, 1992) found that kids born with low birth weights grow slower than those born with high birth weights. Thus single born kids are heavier at birth and maintain the superiority up to weaning and post weaning phases (Das *et al.*, 1989; Djemali *et al.*, 1994 and Kiango, 1996). Other information on body weights of various breeds at different ages is shown in Table 2.

Table 2: Body weights (kg) of various breeds of goats at different ages

Age group	Breed	N	Sex		Mean	Source
			M	F		
Adults	Tanzania local	-	37.0	30.0	33.5	Kyomo (1978)
Adults	Tanzania local	-	30.0	24.0	27.0	Abunie (1992)
Adults	Tanzania local	64	36.7	33.50	34.2	Madubi (1997)
Adults	Malawi local	-	28.0	21.0	24.5	Reynolds (1986)
Adults	Malawi local	50	45.0	32.0	38.0	Karua &Banda (1992)
Adults	Malawi local	-	37.0	29.0	33.0	Banda *et al.* (1993)
Adults	India Local	-	17.2	22.10	19.0	Bose & Basu (1984)
Growers	W.A. Dwarf	-	19.0	18.0	19.5	Seifert & Wuschko (1992)
Growers	Tanzania local	61	17.6	17.0	17.0	Madubi (1997)
Weaners	Blended	134	-	-	10.0	Das *et al.*, (1989)
Weaners	Tanzania local	-	12.3	9.8	-	Madubi, (1997)
Preweaners	W.A. dwarf	-	9.3	9.1	9.2	Seifert&Wuschko (1992)

2.3.1.6 Nutritional effects

There is abundant evidence that nutrition influences growth performance in goats. Growth rate in goats generally increases as levels of energy and protein increases in the diet (Kitalyi, 1982) .The availability and quality of forages varies from one agro-ecological zone to another and this may result into differences in body weights of the same breeds of goats. In Tanzania, growth rate of goats can be doubled or tripled by proper nutrition (Mtenga *et al.*, 1994) and that, under high and balanced plane of nutrition the genetic make up of the animal becomes the overriding factor of growth rate.

2.3.1.7 Genetic effects

Several studies (Bradford and Berger, 1988; Mourad, 1993) have been carried out to examine the effect of breed on pre-weaning growth traits. Breed variation on weaning weight has also been reported by many authors like Kyomo (1978) and Abunie (1992). In Africa, Boer goats have excelled other local goats and other European goats in weaning weight (Abunie, 1992).

Generally exotic breeds grow faster than indigenous breeds. Further more, there is a positive correlation between birth weight and adult body size (Morand-Fehr, 1981). Malick *et al.* (1986) working on Beetal, Black Bengal and Black X Beetal goats, reported significant differences in birth weight between these breeds. This variation is expected since birth weight is correlated with mature body size and different breeds have different mature sizes (Abunie, 1992).

2.3.2 Heritability

Heritability is among the most important genetic parameters in animal breeding (Kifaro, 1984). It is broadly defined as the proportion of the total phenotypic variance, which is caused by genetic variation (Falconer and Mackay, 1998), while heritability in the narrow sense estimates the importance of differences in additive gene effect to the phenotypic variance. Heritability for birth weight and post weaning body weights has been reported to be moderately high. Malick *et al.* (1986) indicated heritability of birth weight in goats to range from 0.10 to 0.46, whereas Roy *et al.* (1989) reported heritability ranging from 0.22 to 0.55 for the same trait. The heritability of yearling weight was observed to vary between 0.2 and 0.6 (Roy *et al.*, 1989). Herald (1994) categorized heritability estimates as low/weak (0 – 0.2), moderate/ medium (0.21 – 0.39) and high/strong (0.4 – 1). Heritability estimates of goats for different parameters are presented in Table 3.

Table 3: Heritability estimates in goats

Parameter	h^2	Age (months)	Source
a) Live weight			
Birth weight	0.09-0.43	-	Herald (1994)
Weaning weight	0.08-0.62	4	Everett&James (1986),Herald (1994
Yearling weight	0.30-0.40	12	Herald (1994), Djemali (1994)
Mature weight	0.30-0.60	-	Everett&James (1986)
Rate of gain	0.11-0.72	2-8	Herald (1994)
b) Helminth resistance			
Packed cell volume	0.32-0.42	2-8	Baker *et al.*, (1991)
Packed cell volume	0.22	10-12	Rohrer *et al.*, (1991)
Packed cell volume	0.44	3-6	Rohrer *et al.* (1991)
Packed cell volume	0.35-0.45	3-6	Albers *et al.*, (1987)
Faecal egg count	0.40	8-12	Rohrer *et al.*, (1991)
Faecal egg count	0.15-0.45	2-8	Baker *et al.*, (1991)
Faecal egg count	0.34	3-6	Albers *et al.*, (1987)
Faecal egg count	0.27-0.34	6-8	Bisset *et al.*, ((1996)

2.3.2.1 Methods used to estimate heritability

Methods used to estimate this parameter depend on the source of information. Basically methods commonly used to determine heritability in small ruminants include half sib covariance, parent offspring regression, sire and dam variance components. Half sib covariance component estimates quarter of the additive gene variation based on within and between sires components, while the parent offspring regression estimates half of the additive genetic records from the dam or sire components (Pirchner, 1983; Falconer and Mackay, 1998).

Heritability is estimated from the degree of resemblance between relatives

$$h^2 = \frac{\sigma^2_A}{\sigma^2_P}$$

Where:

σ^2_A is the additive genetic variance;

σ^2_P is the phenotypic variance.

Heritability can also be estimated using sire variance component

$$h^2s = \frac{4\sigma^2_S}{\sigma^2_S + \sigma^2 e}$$

Where h^2s is the heritability estimated from the sire component, σ^2_S is the sire variance component, $\sigma^2 e$ is the error variance component.

2.3.3 Carcass characteristics

2.3.3.1. Dressing percentage

Dressing percentage (the proportion of carcass weight to slaughter weight) predicts the expected value and quality of the slaughtered animal, this is because DP indicates the expected yield of the carcass. Dressing percentage in goats in the tropics ranges between 45 and 55 percent whereas that of cattle ranges between 45 and 50 percent. In Tanzania reports show that DP in goats ranges from 39 to 43% (Assenga, 1997). However, at the Department of Animal Science and Production, dressing percentage values of 32 to 39% have been reported (Kitalyi, 1982). These dressing percentage values are considerable low compared to dressing percentage of 50-60% in temperate breeds of goats.

Dressing percentage is affected by feeding, breed, sex, slaughter weight, age of the animal, gut fill, method of dressing the animal, type of water provision and transport prior to weighing and dressing. Type of breed may influence dressing percentage of goat meat. Working with goats, Kyomo (1978) observed that local goats dress higher than Boer crosses. Live weight affects carcass quality. Live weight affects carcass quality. Generally, the heavier the weight the higher the dressing percentage of the carcass. Sex can also influence dressing percentage. Castrates have been reported to dress higher than intact males or females (Mtenga *et al.*, 1994). In Tanzania, under natural grazing conditions or feeding of hay without supplementation, extremely low dressing percentage (31 to 40%) have been reported. Gut fill is another factor which affects DP. The content of the gut fill can occupy up to 30% depending on nutritional regimes. Generally the higher the gut fill the lower the dressing percentage (Assenga, 1997). According to ARC (1980) a ration with high protein content lowers gut fill, while that of higher fiber content increases gut fill. Furthermore a negative relationship between digestibility and gut fill have been observed (ARC, 1980), that is, factors which improve digestibility will result into reduced gut fill and improved DP. However, there is limited information on DP of goats under traditional management systems. Some of the reported live weights and dressing percentages of goats are presented in Table 4.

Table 4: Live weights (kg) and dressing percentages of some goats in the tropics and subtropics

Breed	Location	Live weight (kg)	Dressing %	Source
Local goat	Tanzania	38.5	46.7	Massae (1984)
Local goat	Tanzania	21.9	44.7	Kyomo (1978)
Desert goat	Sudan	34.7	48.2	Wilson (1983)
SEA	Rwanda	35.7	47.8	Wilson&Murayi (1988)
Local goat	Botswana	32.4	43.4	Owen *et al.* (1977)
Local goat	Tanzania	23.4	43.4	Assenga (1997)
SEA	Tanzania	25.8	42.5	Assenga (1997)

2.3.3.2.Carcass weight

As afore-mentioned, body weight is one of the most important predictors of carcass yield and other carcass traits. Average carcass weights of goats from different parts of the world range from 10 kg (Africa) to 24 kg (Near east and Far east) with an overall mean of 12 kg (Devendra and McLeroy, 1982b). It has been observed that heterogeneity in carcass yield and quality emanates from differences in age, breed, nutrition, and sex (Owen *et al.*, 1978). Mtenga and Kidunda (1986) reported that the weight of edible meat from goats is significantly correlated with body weight.

2.3.3.3 Carcass composition and quality

Carcass composition refers to the proportion of muscle, bone and fat. It varies according to species, age of the animal and live weight at slaughter. Species has influence on carcass composition; goats have higher proportion of joint muscle weight in breast and fore leg. This is because goats are aggressive and agile in nature. A higher plane of nutrition increases the percentage of fat while under nutrition reduces fat percentages and to some extent retards muscle development (Berg and

Butterfield, 1976). Several studies have shown that among the three tissues, fat is the most variable carcass component in the body (Kyomo, 1978; Kitalyi, 1982). Fat plays an important role in carcasses as it contributes to the keeping appearance, quality and yield value of the carcass (Nyaki, 1981). In Tanzania several studies (Nyaki, 1981; Kitalyi 1982) have shown that fat composition in goats varies from 6.7 to 14.5% depending on the plane of nutrition, whereas lean content occupies 65% of the total composition of the carcass. On station studies have reported that lean content in goats ranges from 60 to 70%. Goats carcasses have thin fat cover, but with high proportion of muscle and bone. Studying the carcass composition of goats, Kirk *et al.* (1996) observed better muscle development in the neck, thorax and forelimb regions; the fat contents were found to be concentrated around the viscera. An ideal carcass should contain maximum lean, just enough bone to support the animal and optimal level of fatness depending on fat requirement of the market (Cutchbertson *et al.*, 1972; Simm, 1992) and that, leanness of meat is the major criterion by which consumers judge quality cover at the shop counter.

2.3.3.4 Non-carcass components

In most tropical countries, non-carcass components are of significant importance because they are edible, saleable and contribute to the overall supply of animal protein (Assenga, 1997). In dressing the animal, some of these components are left with the carcass depending on the market and country. Presence or absence of the non-carcass components on the carcass will influence dressing percentage. Kitalyi (1982) developed total edible and saleable indices of 73% and 82% respectively. The edible non-carcass components include: the head, liver, kidneys, skin, feet, tongue, brain, cheeks, intestines, lungs, spleen, blood, and even fat (Kirton, 1988). This suggests that offal weight is a proportion of total edible meat in most tropical countries. The offal comprises 33% of total edible components in Botswana, Malawi and Nigeria (Owen, *et al.*, 1977; Aduku, *et al.*, 1991).

Working on goats and sheep in India, Acharya (1988) reported two reasons for inclusion of offal to the total edible portions. First they are widely consumed in various ways and secondly, their value offsets the cost of slaughter. In Tanzania, non-carcass components are valued differently among different tribes. For example, some tribes from the lake zones consume the intestines separately or mixed with blood. Most members of the community like it, whereas in Kilimanjro region blood is used to prepare a drink commonly known as *kisusio* (Assenga, 1997).

2.4 Worm burden

Helminthosis in livestock is of considerable significance in a wide range of agro climatic zones in Africa. It constitutes one of the most important constraints to small ruminant production. Further more, sub-clinical manifestation which largely goes unnoticed, is an important form of infection economically since it occurs in majority of cases leading to retarded growth, delayed and reduced erythropoetic capacity (Shavulimo *et al.*, 1988; Ndarathi *et al.*, 1989; Bekele *et al.*, 1995; Waller, 1997). Other associated losses are costs of anthelmintics, condemnation of specific organs viz cirrhotic liver during meat inspection, death of infected animals and increased susceptibility to other infections. Goat mortality rate of 54% (Baker, 1995) and 64.4 % (Mboera and Kitalyi, 1994) due to gastrointestinal nematodes have been reported in Central Tanzania and Zaire respectively. It is estimated that blood-sucking adult helminth e.g. *Haemonchus ssp* may suck about 0.01 ml of arterial blood in a day, leading to rapid deaths of goat kids in heavily helminth infected areas.

Assessment of worm burden in animals uses indicator/infection traits and predictor traits. Examples of indicator traits are faecal egg count (FEC), packed cell volume (PCV), aesinophil count (EOS) and resilience. FEC is the most direct measure used to evaluate resistance of goats to gastrointestinal nematodes as well as identifying the nematode species through faecal cultures under both natural and artificial infections. It is an indicator trait because it indirectly measures worm numbers that are used to define resistance. FEC has been established as a good indicator of worm burden. Baker (1995) reported a correlation coefficient of 0.74 between individual FEC and worm counts in sheep of twelve months of age. Working with two-year-old animals (Phiri and Mungomba, 1998) observed a strong correlation (r = 0.75) between FEC and total worm burden. In adult animals, FEC can be used to determine the extent and intensity of gastrointestinal parasites in a flock and may act as an indicator of the level of pasture contamination (Tekelye *et al.*,1987). For instance, Soulsby (1982) contented that an epg of at least 2000 is needed to cause clinical helminthosis. Another study by Baker *et al.* (1995) revealed that, in small ruminants, an epg above 1000 is considered heavy and in kids/lambs treatment is advisable. Moreover, Shulaw (2001) suggested deworming in small ruminants when the average of FEC of 100-200 epg is reached so as to prevent pasture contamination. Hansen and Perry (1994) categorised FEC in young animals with mixed gastrointestinal infections as light (50-800), moderate (800-1200) and heavy (> 1200).

PCV is another important parameter used to determine the level of helminth parasitism particularly to blood-sucking helminths like *Haemonchus contortus*. It measures the degree of anaemia (Baker, 1995). Baker *et al.* (1995) observed that an increase in worm infestation was associated with decreased PCV. Thus, heavy infections led to low PCV which ranged between 8 and 22% (with an average of 15%).

On the other hand EOS measures the degree of immune response to the gastrointestinal nematode infection. EOS kills parasitic helminths in the presence of specific antibody immunoglobin G (IgG). Waller (1997) recognized EOS as effectors cells in *invitro* destruction of helminths and that, Master cells and immunoglobin E (IgE) enhance the effect of EOS mediated killing. The use of EOS count as an indirect selection trait for FEC would have been 40% as efficient as using FEC itself. Predictor traits include enzyme linked immunosorbent assay (ELISA), haemoglobin (HB), lymphocyte antigen type, whole blood lymphocyte culture, which assist to know the presence and type of worms in question.

2.4.1 Factors affecting resistance of small ruminants to helminths

There are many factors known to affect the acquisition of resistance of small ruminants against gastro intestinal helminths. The most important are size of the challenge, sex and age of animal (Gruner *et al.*, 1986; Barger, 1989), nutrition, physiological state, breed, presence or absence of intercurrent infection (Hansen and Perry, 1994a).

There is a decrease of worm burden in small ruminants with increasing age. Old animals are more resistant than neonates. Kids and lambs are more susceptible to infection with helminth than adults (Assenga, 1992). This is due to the fact that young animals are incapable of developing immunity because their immune systems are still immature (Kusiluka, 1995). This could be attributed to competing demands for available nutrients between growth, repair of gastrointestinal pathology and immune response (Coop, 1996). He further suggested that in growing lambs/kids there might be a bias towards growth and repair at the expense of development of immunity.

Sex of the goat has an effect on the resistance to worm burden. Working with the indigenous West African goats, Assoku (1981) observed that buck kids had significantly lighter worm burden than the doe kids. Moreover, females at puberty had better resistance to worm burden than females. Oestrogen and androgen have both immunostimulatory and immunoinhibitory, respectively, largely by their action on T-helper and T-lymphocytes (Crossman, 1985).

Physiological status of the host may affect resistance to gastrointestinal helminths. It has been found that in ewes and does, hormonal changes during late pregnancy and lactation lower the resistance of the host to nematodes and consequently result into establishment of higher worm burdens (Fleming, 1993). Prolactin has been implicated as a modular of periparturient egg rise in ovine and caprine nematodes. Post parturient rise (PPR) in faecal egg count in lactating does and ewes is related to the increase in the fecundity of adult worms already in the alimentary canal and non-specific immunological loss of resistance by the does and ewes as a result of stress factors of lambing/kidding. Findings by Keyyu (1998) indicated that resistant breeds/strains have a less PPR compared to susceptible ones. Hansen and Perry (1994b) stated that physiological stress such as parturition may affect the extent of gastrointestinal nematode infection in animals. Furthermore, Allonby (1980) noted that pregnancy may influence the outcome of helminth infections. Ewes tend to lose immunity to helminths around the time of parturition and during lactation (Barger, 1989). This could be attributed to high level of prolaction which might have immunosuppressive effect (Sykes, 1994).

The resistance to helminthosis can also be affected by weaning of young animals. Weaning increases the degree of susceptibility to infections. That is, the physiological response associated with stress of weaning (especially elevation in glucocorticoids) result in immunosuppresion and consequently may lead to increased susceptibility to pathogenic infection (Watson, 1991).

Breed differences in the susceptibility or resistance to gastrointestinal helminth infections have been documented. Assoku (1981) found that indigenous West African Dwarf goats in Ghana were more resistant or tolerant to gastrointestinal helminth infections than exotic breeds. Shavulimo *et al.* (1988) observed that Small East African goats were more resistant to *Haemonchus contortus* than their crosses with Toggenburg and Galla goats. Baker (1995) reported that the indigenous goats in East Africa are more resistant to helminthoses than the imported exotic breeds. The criteria used to select resistant breeds to worm burden is based on indicator/ infectious and predictor traits (Eady, 1995).

The resistance to gastrointestinal nematodes is also influenced by the level of nutrition. Starvation or deficiencies of nutrients such as vitamins, protein or minerals lowers the resistance of the animal and enhances the establishment of worm burdens in the host (Assanji, 1988). He also demonstrated that malnutrition during dry season lower the resistance of sheep and goats to *Haemonchus contortus* infection even when environmental factors are unfavorable for larvae development. According to Allonby (1980) poor nutrition increases the pathogenicity of helminth infection. Animal fed on higher plane of nutrition (especially protein diet) are able to resist the consequence of infection (Gimbi, 2000).

The level of infection influences the extent of immunity acquired to challenge infection (Gimbi, 2000). A high initial infection may produce an immune block, which decreases the animal's resistance to challenge infection. Moreover, animals given very low initial infection required a longer period to develop resistance and that trickle infections enhance development of resistance than animals given a single primary infection (Keyyu, 1998; Gimbi, 2000). The multiplication rate of worms, which is determined by the fecundity of the adult worms, affects the acquisition of resistance. Different nematode species differ in their fecundities. *Haemonchus contortus* and *O. colombianum*, for example, are known to have high biotic potential such that the establishment of *H. contortus* populations occur very rapidly as long as the environmental factors are favorable for translation and transmission while *Trichostrongylus spp* are known to have a lower biotic potential.

2.4.2 Effects of worm burden on growth rate of goats

Helminth infections in goats are mainly caused by three worm genera namely, Trichostrongyles, Oesophagostomum and Bunostomum. Hansen and Perry (1994) categorized the pathogenic effects of helminthosis as sub-clinical and clinical forms. Sub-clinical effects of worm infestations are hardly recognised by most farmers. Detrimental effects of worm burden on productivity manifest in a variety of ways. According to Waller (1997) changes of body weight was noted as the predominant feature of worm infestations. Fox (1997) reported depression in feed intake due to worm infection as an important cause of reduced weight gain and anaemia. Other effects are impaired digestion and utilization of proteins which may lead to low blood protein, progressive weight loss and even death in young animals. The main sign of serious low blood protein is oedema under sub-mandibular region. Helminthosis sequels are also associated with trace mineral deficiency, irritation of the gut and toxins production which impairs growth performance of animals. Hansen and Perry (1994) reported that anaemia in infected goats is the principle feature of Haemonchosis. It has been estimated that each blood sucking adult worm e.g. Haemonchus spp may suck about 0.01ml of arterial blood in 24 hours. This may kill the affected goats within a very short time in case of heavy haemonchosis infection (Kassuku and Ngomuo, 1997). Moreover, destruction of gastric and intestinal mucosa by nematodes results into pathophysiological disturbances such as decreased PH, extensive atrophy of villous and mal-absorption of nutrients in severely affected goats. This may lead to reduced skeletal growth and bone matrix osteoporoses (Sykes, 1994), hence poor growth rates and other malformations.

2.4.3 Measurement of disease resistance of goats

Criteria used to detect resistant animals are genetic or molecular markers used in [e.g. gene mapping (Smith and Smith, 1993), restriction fragment length polymorphism (RFLP) and genetic finger-printing (Nicholas and Blatman, 1994)]; faecal egg counts (FEC); Haematocrit or packed cell volume (PCV); Blood eosinophil counts (EOS), total white blood cells (WBC), haemoglobin (HB); blood chemistry; immunological methods e.g. enzyme linked immunosorbent assay (ELISA) and mode of infection (Eady, 1995).

Faecal egg counts (FEC) is the most commonly measured trait to detect resistance of animals to helminths. It is also used for diagnosis of gastrointestinal nematodes' infection and is considered to be an important trait as it is related to the level of pasture contamination and the level of infection to which grazing animals are exposed (Gray, 1991). The method involves recovery of eggs from the digestive tract of an animal or from faecal material (Hansen and Perry, 1994b). Separation of eggs from faecal material or gastrointestinal contents is usually done by floating using saturated sodium chloride solution. The eggs are then microscopically counted on a McMaster counting chamber (MAFF, 1986), and expressed as number of eggs per gram (epg) of feaces. The standard faecal suspension for helminth egg identification is prepared according to Urguhart and Sewell (1992). Strong correlation has been indicated between the epg and the number of nematodes in sheep and goats especially in young animals (McKenna, 1981)

Factors which can limit the accuracy of FEC include uneven distribution of eggs in faeces, fluctuations in faecal output, presence of immature worms, resistance of the host and consistency of faeces (Hansen and Perry, 1994b). Moreover, FEC can be affected by age, sex, species, health and physiological status of the animal as well as the age of nematode population (Tekelye *et al.*, 1987). Due to these factors, the epg of the faeces is not always directly correlated with the total worm count in the animal. Sex of the animal affects the FEC. Generally, female animals tended to have higher FEC than males (Assoku, 1981; Keyyu *et al.*, 2001). Breed of the animal affects faecal egg counts. Dodoma strain had lowest FEC and Mtwara had highest FEC, while Kigoma strain had FEC between the other two strains (Keyyu *et al.*, 2001).

The packed cell volume (PCV) is among the haematological tests used in detection of helminth infection and resistance of animals to gastrointestinal helminths and it is related to the degree of anaemia in the affected animals. For instance, high level of PCV has been reported to be associated with low degree of anaemia, while low level of PCV is related to high degree of anaemia (Gimbi, 2000). PCV is determined using the haematocrit centrifuge technique as described by MacLeod *et al.*, (1981).

Different factors influence PCV in goats. Tekelye *et al.* (1987) reported breed, age, lactation and pregnancy to be factors which influence PCV in goats. Breed differences in PCV of goats have been documented. Wesonga *et al.* (1989) and Somvanshi *et al.* (1987) reported indigenous SEA goats and Indian goats to have lower PCV than American and European goat breeds. Other studies by Gimbi (2000) and Keyyu *et al.* (2001) reported that Dodoma and Mtwara strains had highest and lowest PCV, respectively, and Kigoma strain had PCV between the other two strains. The effect of age in PCV of goats has been observed. Kids had high PCV (36.6%) at birth and then declined to 33.9% in the next 3 months of age and attained an average of 28.7% (PCV) at about two years of age (Wesonga *et al.*, 1987). Sex of the animal affects PCV in goats. However, studies done by Somnvashi *et al.* (1987) and Gimbi (2000) reported that sex had no significant influence in PCV of Indian goats and SEA goats, respectively.

2.5 Linear body measurements

Linear measurements used in predicting body weights and carcass values in goats include body length, heart girth, withers height and height at rump. Individual or combined body measurements, which yield high correlation with carcass weight, have been used as simple indicators and predictors of live weight (Hassan and Ciroma, 1990). Valdez *et al.* *(*1982), Berhanu *et al.* (1992) and Assenga (1997) reported heart girth to be the best predictor of body weights, accounting for 75-78% of the variation in body weight; while the body length was found to be the worst predictor, accounting for about 60-72% of the variation in body weight. Contradicting findings have been reported by Hassan and Ciroma (1990) where body length had the greatest accuracy of predicting body weight compared to heart girth. On the other hand, Madubi (1997) working with Tanzania local goats found that heart girth, wither weights and body length were good predictors of body weight. However, very little information on the effect of linear body measurements on carcass weight and composition has been reported. Therefore, more research is still needed to confirm which body measurements can accurately be used to predict body weight and carcass weight. Some body measurements done in Tanzania and India are shown in Table 5.

Table 5: Body measurements of mature goats

Strain	Location	Trait	Male	Female	Source
SEA	Tanzania	BW	37.0	30.0	Kyomo (1978)
		BL	57.7	57.6	
		HG	73.0	73.3	
		WT	57.8	61.3	
		WH	40.8	33.4	
Boar	Tanzania	BW	40.8	33.4	Kyomo (1978)
		BL	63.5	63.5	
		HG	80.6	69.3	
		WH	67.5	63.5	
Kamorai	Tanzania	BW	44.0	31.0	
		BL	67.3	65.1	
		HG	84.4	74.3	
		WH	60.6	60.4	
Local	India	BW	17.2	22.1	Bose&Basu (1984)
		BL	56.7	61.6	
		HG	72.2	68.7	
		WH	60.15	64.2	
Local	Tanzania	BW	22.7	23.7	Assenga (1997)
		BL	52.9	53.8	
		HG	67.6	68.6	
		WH	59.6	56.0	

2.6 Sample joints and linear body measurements as predictors of carcass composition and weight.

Carcass composition is determined by total dissection of the whole carcass into separate lean, fat and bone. Although this technique is time consuming, it is more realistic as it is directly related to the marketing of carcass (Owen *et al.*, 1978; Kyomo, 1978; Nyaki, 1981). The criteria to select a suitable predictor is based on cost, accuracy, precision and their practicability. The predictors which are commonly used include the hind leg, fore leg, loin, chump, breast, ribs, neck, shoulder and scrag /neck joint weights, or as percentage of the whole carcass. Separate tissues in these joints have also been used as predictors of carcass composition. One of the cheapest and simple methods of predicting carcass composition is the dissection of sample joints (Nyaki, 1981). This has been possible because there is a close relationship between the composition of individual joints and the overall carcass composition.

The relationship between carcass joints and carcass composition can be affected by sex, breed and environmental factors. Butterfield (1965) advocated that live weight, shrunk body weight and carcass weight should be used as indices of carcass composition, while Kempstor *et al.* (1976) observed that the rib joints are better predictors of percentage of intra-muscular fat and subcutaneous fat. Furthermore, Bergstron (1975), Kempstor *et al.* (1976) and Daka (1987) pointed out that the weight of the loin, breast, best end neck, 7-9th rib joint weight give more accurate estimate of carcass composition (muscle, bone and fat). Butterfield (1965) reported that muscle is most accurately predicted by thin muscle weight plus cold carcass weight and fat thickness in cm measured at 10-11th rib joint.

Assenga (1997) working on Tanzanian goats and sheep reported that the hind leg and rib joints were the best predictors of the carcass muscle, and can explain most of the variations between muscle, bone and fat in the carcass. The neck, breast and chump joints were poor estimates of total carcass muscle in goats. Multiple regression analysis involving pairs of sample joints showed that leg plus loin were the most accurately correlated joints with carcass composition (Timon and Bichard, 1965).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Part I of the study

3.1.1 Introduction

The main aim of this part was to evaluate the effects of factors affecting growth rate of goats, which included sex, strain, birth type, year of birth and worm burden (FEC and PCV) using records accumulated at the Department of Animal Science and Production. In addition, heritability estimates for birth weight, growth rates, and weights at 4, 8 and 12 months and disease resistance traits were determined.

3.1.1.1 Study area

This study was carried out at the Department of Animal Science and Production of the Sokoine University of Agriculture, Morogoro, Tanzania. The dominant flora found at the University farm according to Kyomo (1978) are: grasses, herbaceous legumes, tree legumes, Hibiscus spp and undesirable species like *Sporobolus spp*, *Lantana camara* and spear grasses. This flora still exist to date.

3.1.1.2 Experimental animals

The experimental animals were three strains of Tanzania local goats namely Mtwara, Dodoma and Kigoma. They belong to ENRECA project and they have been kept in the Department of Animal Science and Production since 1996. About 243 animals from Mtwara, Kigoma and Dodoma were bought in 1996 for on station testing at SUA. Out of these 72, 81 and 90 were from Mtwara, Kigoma and Dodoma respectively.

3.1.2: Effect of sex, birth type, strain, and year of birth on growth rate of goats

3.1.2.1 Data collection

Breeding records accumulated by the ENRECA project between 1997 and 2000 were used for this study. The records included weights of goats at different ages i.e. at birth, at weaning (4 months) and at one year of age.

3.1.2.2 Data handling

Growth rates at different age intervals i.e. pre weaning (birth to 4 months), post weaning (4 to 8 months) and yearling (8 to 12 months) growth rates were calculated by the following formula:

$$GR = \frac{W_2 - W_1}{T_2 - T_1}$$

Where:

GR = Growth rate

W_1 = Previous weight. (e.g. birth weight)

W_2 = Weights at 4, 8, 12 months (yearling weight)

Weights at weaning (4 months), 8 and 12 months of individual animals were adjusted for age before being used for computing growth rates as described by Kiango (1996). The formula used was as follows:

$$Adjwt = \frac{(W_2 - W_1) \text{ x S days}}{T_2 - T_1}$$

Where:

Adjwt = Adjusted weight (4, 8 months and 12 months).

W_1 = weight at previous age (e.g. at birth, weaning)

W_2 = Actual weight at 4, 8 and 12 months

$T_2 - T_1$ = Time interval between the two periods in days (e.g. between birth and weaning at 4 months)

S days = specified age in days (120, 240, 365 days)

3.1.2.3 Data analysis

The effect of sex, strain, birth type and year of birth as fixed effects on growth rate were evaluated using the General Linear Models (GLM) procedure of the Statistical Analysis System (SAS, 1996).

Model 1

Data were analysed for the effect of sex, strain, birth type and year of birth on growth rates at 4, 8, and 12 months of age using the following model:

$Y_{ijklm} = \mu + T_i + B_j + S_k + Y_l + (T*Y) + (S*B) + e_{ijklm}$.

Where:

Y_{ijklm} = Growth rate of m^{th} individual in l^{th} year of birth, k^{th} sex, jth birth type and i^{th} strain.

μ = General mean

T_i = Effect of i^{th} strain (i=1,2,3 i.e.1=Dodoma, 2=Kigoma, 3=Mtwara).

B_j = Effect of $_j^{th}$ birth type (j=1,2 i.e.1=single, 2=multiple).

S_k = Efect of k^{th} sex (k=1,2 i.e. 1=male, 2= female).

Y_l = Efect of l^{th} year of birth (l=1.2.3.4 i.e. 1=1997, 2=1998, 3=1999, 4=2000).

$(T*Y)_{il}$ = Interaction effect between i^{th} strain and l^{th} year of birth.

$(B * S)_{jk}$ = Interaction effect between j^{th} birth type and k^{th} sex .

E_{ijklm} = Random error specific to each individual.

3.1.3 Effect of worm burden on growth rate of goats

Records of weights, FEC and PCV for each goat at six and twelve months of age were used in this study.

3.1.3.1 Data handling

Growth rates at different age intervals i.e. (five to 6 months) and between 11 and 12 months) were calculated.

Weights at weaning (6 months), 12 months of individual animals were adjusted for age before being used for computing growth rates as described by Kiango (1996).

In order to evaluate the effect of worm burden on growth rate at six and twelve months, FEC were classified in four (4) levels (i.e. <700 = 1, 701-1400 = 2, 1401-2100 = 3, >2100 = 4). PCV percentages were also grouped in 4 levels (<18 =1, 19-25 =2, 26-32 =3, >32 = 4).

3.1.3.2 Data analysis

Analysis of growth rate of goats as affected by worm burden was done according to the General Linear Models (GLM) procedure of the Statistical Analysis System (SAS, 1996). The sets of data for FEC and PCV were transformed before analysis. The transformations were done as follows: LFEC = [$\log_{10}$ (FEC + 25), LPCV = $\log_{10}$ (PCV+10)] for FEC and PCV, respectively. The results were then transformed back by taking the antilogarithms of the least square means of FEC and PCV. Birth weight was used as covariates in the model.

Model 2

The following model was used:

$Y_{ijklmn} = \mu + S_i + B_j + S_k + Y_l + Fm + Pn + b_l (X_{ijklmn} - \overline{X}) + e_{ijklmn}$.

Where:

Y_{ijklmn} = Growth rate of an individual.

μ = General mean.

S_i = Effect of i^{th} strain.

B_j = Effect of j^{th} birth type.

S_k = Efect of k^{th} sex.

Y_l = Efect of l^{th} year of birth.

F_m = Effect of m^{th} category/level of faecal egg count.

P_n = Effect of n^{th} category/level of packed cell volume.

b_l = Regession of X_{ijklmn} on birth weight.

X_{ijklmn} = Birth weight of an individual.

$\overline{X}$ = Mean birth weight

E_{ijklmn} = Random error specific to each individual.

Data were thereafter re-run with FEC and PCV as covariates in order to get regressions of growth rate on FEC and PCV values and correlation between the three variables. Data were assumed to be described by this model

Model 3

$Y_{ijklm} = \mu + T_i + B_j + S_k + Y_l + b_l (X_{ijklm} - \overline{X}) + b_2 (P_{ijklm} - P) + e_{ijklm}$.

Where:

Y_{ijklm} = Growth rate of m^{th} animal in l^{th}year of birth, k^{th} sex, j^{th} birth type and i^{th} strain.

μ = General mean

T_i = Effect of i^{th}strain.

B_J = Effect of j^{th}birth type.

S_k = Efect of k^{th} sex.

Y_l = Efect of l^{th} year of birth.

X_{ijklm} = Faecal egg count of an individual.

$\overline{X}$ = Overall mean of faecal egg count.

b_1 = Regession of y_{ijklm} on x_{ijklm}

P_{ijklm} = Packed cell volume of an individual.

P = Overall mean for packed cell volume.

b_2 = Regression of y_{ijklm} on p_{ijklm}.

E_{ijklm} = Random error specific to each individual.

PCV and FEC values were further subjected to analysis of variance for fixed effects of sex, strain, year of birth and birth type. The main aim was to look into strain differences in resistance to worms.

3.1.4 Estimation of heritability

3.1.4.1 Data collection

Breeding records accumulated by the ENRECA project from 1997 to 2000 were used for this study. These records included weights of goats at birth, 4, 8 and 12 months of age and helminth resistance parameters i.e. FEC and PCV at six and twelve months of age.

3.1.4.2 Data analysis

Heritability of growth rate between birth and four months, between four and 8 months and between 8 and 12 months; weights at birth, weaning (4 months), 8 and 12 months of age; FEC and PCV at six and 12 months was estimated using the REML method of the Var comp (variance component) procedure of the Statistical Analysis System (SAS, 1996) which gave half sib sire components (σ^2_s) and the error variance components (σ^2_e). The standard error (se) of the heritability values was obtained using the following formula:

$$se = \frac{\text{Root EMS}}{\sqrt{n}}$$

Where: Root EMS = Root error mean square from the analysis of variance of the data, n is the total number of observations.

Heritability was obtained by multiplying σ^2_S by 4 to get the additive genetic variance divided by σ^2_P which was obtained by summing up σ^2_S and σ^2_e (error var),

Model 4

Heritability was estimated by the following formula:

$$h^2s = \frac{4\sigma^2_S}{\sigma^2_S + \sigma^2 e}$$

Where:

$4\sigma^2_S$ = Additive genetic variance,

σ^2_S=Sire variance component,

σ^2_e = Error variance component,

$\sigma 2^S + \sigma^2_e$ = Total phenotypic variance.

3.2 Part 2 of the study

3.2.1 Introduction

The aim of this part of study was to evaluate the effect of three strains of goats on killing out characteristics and physical carcass composition. In addition, prediction equations were developed for estimation of carcass weight and carcass tissues using linear body measurements and carcass joints, respectively. Equations for estimating carcass composition using carcass weight, empty body weight and slaughter weight were also developed.

3.2 2 Evaluation of killing out characteristics, physical carcass composition and development of prediction equations

3.2.2.1 Animals

Twenty seven (27) male goats with the age of about 2 years from the Department of Animal Science and Production at SUA were used in this study. These goats belonged to three strains of local goats i.e. Dodoma, Mtwara and Kigoma. From each strain 9 male goats were slaughtered.

Plates 1 to 3 show some of the experimental animals. According to Madubi (1997) all three strains of goats fall under the Small East African breed and they look phenotypically alike for most characteristics except for the aspect of mean body weight, linear body measurements, which are lower for Kigoma goats. Coat colours vary between and within strains.

Plate1: Dodoma strain buck

Plate 2: Kigoma strain buck

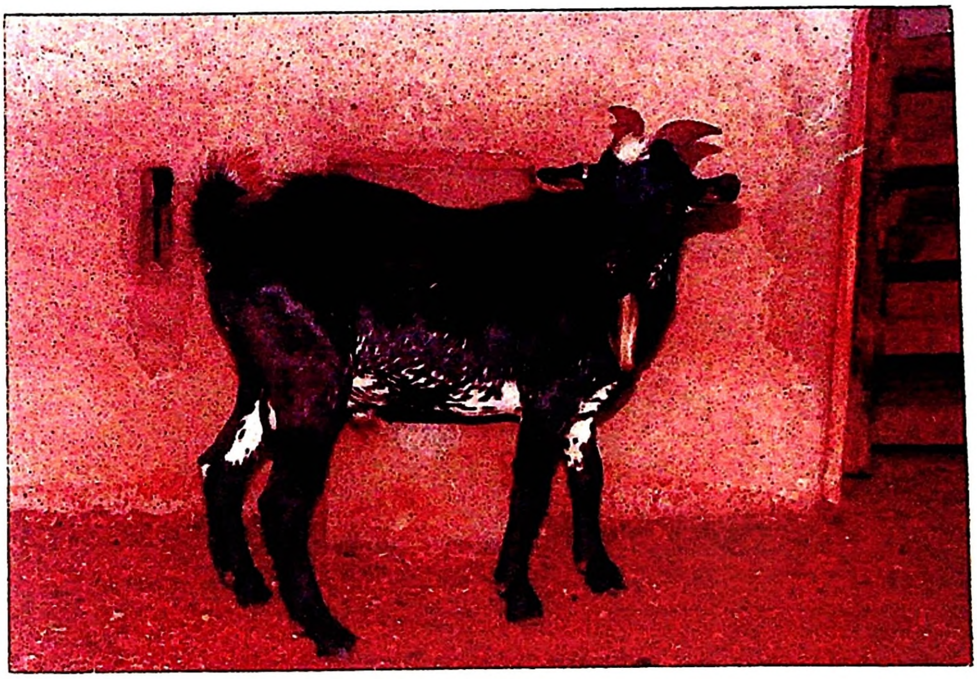
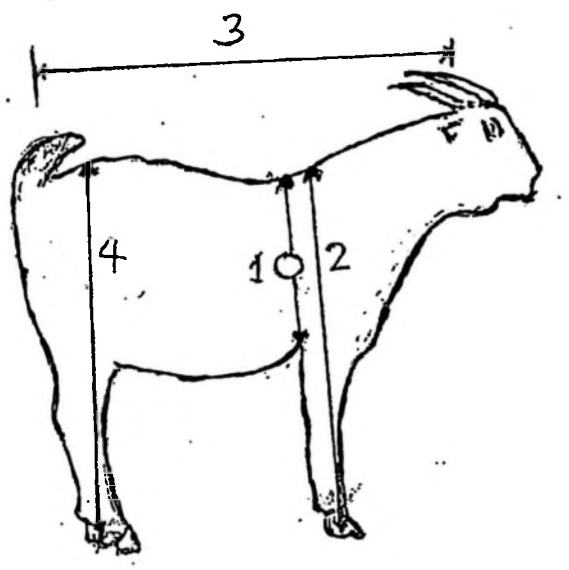


Plate 3: Mtwara strain buck

3.2.2.2 Linear body measurements and slaughter procedure

Before slaughtering the animals, the following linear body measurements were taken using a tailor's tape: External body length, height at withers and height at the rump with exception of heart girth which was measured using a Manson's steel measuring tape. The external body measurements taken prior to slaughtering are shown in Figure 1. The slaughtering procedure was done according to Kyomo (1978). Animals were starved for 24 hours to minimize the effect of variation due to gut fill, and then reweighed to obtain shrunk or final weight at slaughter. Slaughtering was done by severing the carotid artery and jugular veins on both sides of the neck using a sharp knife to cut the neck between the occipital bone (*os occipitale*) and the first cervical vertebrae (atlas) separating the head from the trunk without stunning the animal. Each carcass was bled by hanging it from the hind legs and the free draining blood was collected in a small plastic bucket and then weighed immediately on a spring balance. Hot dressed carcass weight (HCW) was taken immediately after skinning. The gut was immediately stripped and then emptied. The weight of the gut was subtracted from the weight of the goat just before slaughter (taken to the nearest 50g) to get the empty body weight (EBW). The weight of the contents was added to the overnight loss in weight of the animal to obtain the gut fill.

The non-carcass components were removed as recommended by Berhanu *et al.* (1992). The following non carcass components were separated, weighed and immediately recorded: skin, head, fore and hind feet, liver, testes, urinary bladder, heart, respiratory tract (lungs and trachea), gut fat and the gut. Hot carcasses were then weighed on a spring balance and recorded.



1. Heart girth

2 Height at withers

3 Body length

4. Height at rump

Figure1: External linear measurements taken prior to slaughtering

3.2.2.3 Linear carcass measurements

After slaughtering of goats, the following measurements were taken:

EBL = External body length, (it is the part of the carcass measured from the thoracic spine to the base of the tail).

IBL =Internal body length, (it is the part of the carcass measured from the anterior edge of *symphis pubis* bone and to the anterior edge of the first rib).

CD = Chest depth,(is the part of the carcass measured at the 9th rib internally).

HL_1 = Hind leg $_1$;(it is measured between the distal end of tarsal bone and the middle of patella).

HL_2 = Hind leg2,(it is measured from the distal end of tarsal bone to the anterior end of the *symphis pubis* bone.(That is, it is measured by a tape from the top end of the tibia to the bottom cut edge of the pubis).

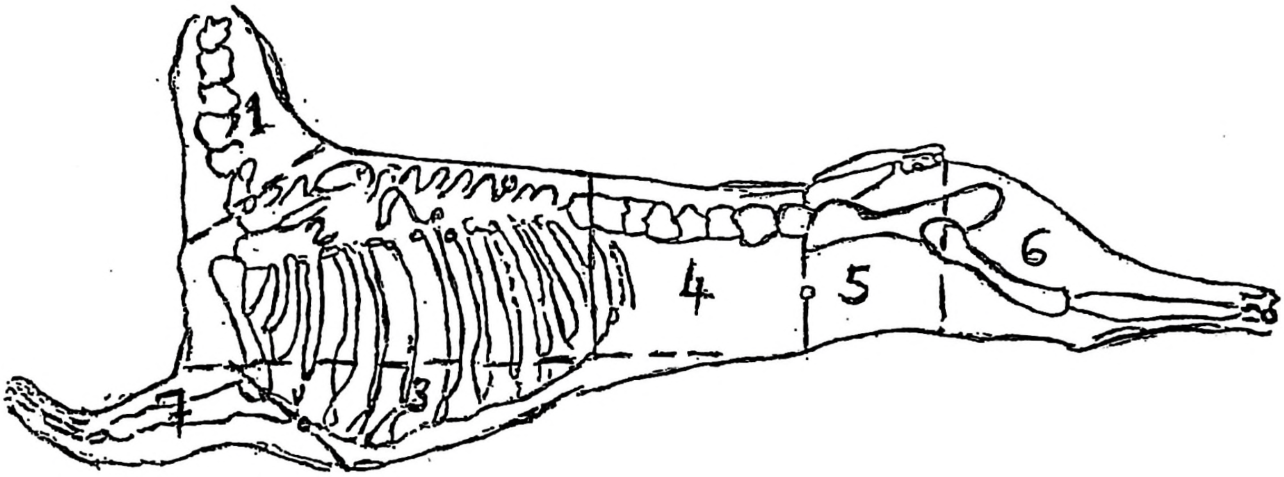
HL_C = Hind leg circumference.,(it is measured around the widest part of the hind leg at the top cut edge of the pubis)

3.2.2.4 Jointing and dissection

The carcass of each goat was split longitudinally into two halves using a special handsaw by cutting along the median plane of the vertebrae from the caudal to the first cervical vertebrae, exposing the spinal cord. The carcasses were chilled in a deep freezer for 24 hours at –4°c and weighed to obtain the left, right and total chilled carcass weights. The right sides of the carcasses were disposed for human consumption, while the left ones were retained for carcass composition determination. Linear carcass measurements such as external body length, internal body length, hind leg circumference and chest depth were taken using a normal linear tape measure.

Using a special handsaw and sharp knife the left sides of the carcasses were jointed into seven standard joints: neck, ribs, breast, loin, chump, hind leg and fore leg according to Kyomo (1978) and weighed. Lean, bone and fat from each cut were scrubbed using a scarpel blade, weighed separately and recorded.

The standard joints of the carcass are shown in Figure 2.



Neck

Ribs

Breast

Loin

5. Chump

6. Hind leg

7. Fore leg

Figure 2: The side of the carcass limb divided into standardized commercial joints

Source: Kyomo (1978)

3.2.3. Data analysis

3.2.3.1 Evaluation of killing out and physical carcass characteristics

Data were analysed according to the General Linear Models (GLM) of the Statistical Analysis System (SAS, 1996). The slaughter weight was used as covariate in analyzing animals' body measurements like carcass weight and empty body weight.

Model 5:

$$Y_{ij} = \mu + B_i + b(X_{ij} - \bar{x}) + e_{ij}$$

Where:

Y_{ij} = carcass characteristics of j^{th} animal of i^{th} strain.

μ = General mean

B_i = Effect of i^{th}strain

b = Regression coefficient

X_{ij} = Slaughter weight of each animal

$\bar{X}$ = Mean slaughter weight of all animals

e_{ij} = Residual effect peculiar/specific to each animal

3.2.3.2 Prediction equations

Simple regression analysis incorporating each linear body measurement of goats was used to estimate carcass weight. The same regression was used to assess strain effect on the non-carcass components as well as estimating carcass composition using carcass joints, empty body weight and slaughter weight.

In addition multiple regression analysis including 2 and then 3 variables together was employed to see if there was an improvement in prediction accuracy of carcass weight and carcass composition. Carcass joints weights, carcass weight, empty body weight, slaughter weight and their combinations were regressed against total lean, fat and bone in the side carcass.

Model 6

The following model presents multiple regression equation used for predicting carcass weight:

$Y_{ijklm} = a + b_1x_i + b_2x_j + b_3x_k + b_4x_l + b_5x_m + e_{ijklm}$

Where:

Y_{ijklm} = Carcass weight

a = Constant.

X_i = Heart girth (HG).

X_j = Height at rump (HR).

X_k = Height at withers (HW).

X_l = External body length (EBL).

X_m = Internal body length (IBL).

$b_1, b_2, b_3, b_4,$ = Regression coefficients.

E_{ijklm} = Random error.

Model 7

The following model presents multiple regression equation used for predicting carcass composition:

$Y_{ijkl} = a + b_1x_i + b_2x_j + b_3x_k + b_4x_l + e_{ijkl}$

Where:

Y_{ijkl} = Total lean or total bone or total fat.

A = Constant.

X_i = Carcass weight.

X_j = Weight of tissues (lean, bone and fat) on joint weights i.e. neck, breast, ribs, loin, chump, fore leg and hind leg).

X_k = Slaughter weight.

X_l = Empty body weight.

b_1, b_2, b_3, b_4, = Regression coefficients.

E_{ijkl} = Random error.

CHAPTER FOUR

4.0 RESULTS

4.1 Part 1 of the study

4.1.1 Growth rate

4.1.2 Effect of sex, birth type strain and year of birth on growth rate of goats

Tables 6 and 7 show overall mean growth rates between birth and 4 months (38.5±2.5g/day), birth and 8 months (35.9±1.5g/day), birth and 12 months 29.8±1.2 (g/day), 4 and 8 months (35.3±1.7g/day) and between 8 and 12 months (29.0±1.6g/day). The least squares means for the effect of sex, birth type, strain and year of birth on growth rate of goats between birth and four months, birth and eight months, birth and twelve months, four and eight months and between eight and twelve months of age are presented in Tables 6 and 7. Analyses of variance for growth rates at different ages and the interaction between strain and year of birth, sex and birth type are shown in Appendix 1.

Between birth and four months of age, year of birth had no significant ($P>0.05$) effect on growth rate of the animals (Appendix Table 1). There was significant influence of sex ($P<0.05$), strain ($P<0.01$) and birth type ($P<0.05$) on growth rate between birth and 4 months of age. Average daily gain of males was 38.7±1.5g against 32.1±1.5g of females, i.e. male kids had 17.0% faster growth rate compared to females. On the other hand, singles had 7.0% faster growth rate compared to multiples. The difference in average daily gain between Dodoma and Mtwara strains was 7.6 g, whereas that between Dodoma and Kigoma strains was 5.2g. Growth rate of goats in 1999 exceeded weight gain of animals from other years albeit the differences were not significant.

Between birth and eight months of age, sex, strain and year of birth had significant ($P<0.05$) effect on growth rate of goat kids. Single born kids had 16.0% faster daily gain than multiples. The difference in growth rate between Dodoma and Kigoma strains was 2.4g/day; while between Dodoma and Mtwara was 8.1g/day (Table 7). Goat kids born in 1997 and 2000 had lowest daily gain (32.7±1.5 and 33.8±2.0 g), whereas those born in 1999 had highest growth rate (37.6±2.5 g). Results revealed that birth type had no significant ($P>0.05$) effect on growth rate of kids.

Between birth and twelve months of age, sex, birth type and year of birth showed insignificant ($P>0.05$) influence on growth rate of kids. Strain on the other hand exhibited a significant effect on the daily gain of goats. Dodoma strain had 19.0% and 1.4% faster growth rate compared to Mtwara and Kigoma, respectively (Table7).

Between four and eight months of age, there was no significant ($P>0.05$) effect of birth type on growth rate, although in absolute terms singles grew faster than multiples. The difference in growth rate between single kids and multiples was 0.5 g/ day. Results show a significant influence of sex, strain and year of birth ($P<0.05$) on growth rate between 4 and 8 months of age. The difference in growth rate between males and females was 6.7g/day. Dodoma strain had 21.8% and 6.4% faster growth rate compared to Mtwara and Kigoma strains, respectively. The highest growth rate

(35.9±9g/day) of goat kids was reported in 1999 whereas kids born in 1997 and 2000 had almost the same growth rate (30.9±1 and 32.1±1g/day).

Strain was the only factor which had significant (P<0.01) influence on growth rate of kids between 8 and 12 months of age. Dodoma strain had the highest growth rate (32.6±2g/day). The difference in growth rate between Dodoma and Mtwara strains was 6.5g/ day, whereas between Dodoma and Kigoma strains was 1.2g/day. Sex, birth type and year of birth exhibited insignificant effect (P>0.05) on growth rate at one year of age.

The interaction between sex and birth type had significant (P>0.05) effect on growth rate of goats in all ages (Appendix Table 1). Male and single kids had superior daily gain to females and multiples. However, the interaction between strains and year of birth had no significant (P>0.05) influence on growth rate of goat kids in all age intervals.

Table 6: Least square means ±se for effect of sex, birth type, strain and year of birth on growth rate at 4, 8 and 12 months of age

		B- 4 months	4- 8 months	8- 12 months
Factors	**Level**	**LSmeans ± se**	**LSmeans ±s e**	**LSmeans ± se**
Overall mean		38.5± 2.5(333)	35.3 ± 1.7 (222)	29.0± 1.6 (195)
Sex				
	Female	32.1±1.7^{a}(173)	29.2±1.8^{a}(112)	26.3±1.0(98)
	Male	38.7±1.5^{b}(160)	35.9±1.4^{b}(110)	27.4±2.2(97)
Birth type				
	Single	35.6±1.7^{a}(241)	32.7±2.1(161)	28.6±1.1(139)
	Multiple	33.1±2.3^{b}(92)	32.2±2.0(62)	28.3±1.5(56)
Strain				
	Kigoma	34.6±1.3^{a}(126)	35.2±1.0^{b}(85)	31.4±1.5^{a}(74)
	Dodoma	40.0±2.6^{b}(149)	37.6±2.5^{b}(100)	32.6±2.3^{b}(86)
	Mtwara	32.3±2.1^{a}(58)	29.4±3.2^{a}(38)	26.1±1.8^{a}(35)
Year of birth				
	1997	35.3±3.4(16)	30.9±1.3^{a}(11)	29.2±1.8(11)
	1998	37.5±3.2(70)	34.5±1.8^{b}(48)	31.1±1.3(43)
	1999	37.7±2.8(150)	35.9±2.4^{b}(195)	30.1±1.3(86)
	2000	35.8±2.3(97)	32.1±2.1^{a}(69))	28.2±1.7(55)

^{a,b} LSmeans bearing different superscripts along the columns within a specific factor are significantly (P<0.05) different.

B-4 months = From birth to 4 months of age

4-8 months = From 4 to 8 months of age

8-12 months = From 8 to 12 months of age

Numbers in parentheses are numbers of goats

Table 7: Least square means ±se for effect of sex, birth type, strain and year of birth on growth rate between birth - 8 and birth-12 months of age

		Birth –8months	Birth-12 months
Factors	**Level**	**LS means ±s e**	**LS means ± se**
Overall mean		35.9±1.5 (222)	29.9 ± 1.2 (195)
Sex			
	Female	30.9±1.5^a(112)	28.0±2.0(98)
	Male	36.6±1.3^b(110)	29.2±1.9(97)
Birth type			
	Single	34.5±1.9(161)	30.4±1.2(139)
	Multiple	33.9±2.1(62)	30.0±1.0(56)
Strain			
	Kigoma	36.9±1.1^b(85)	34.4±1.3^a (74)
	Dodoma	39.3±2.4^b(100)	34.9 ±3.0^a (86)
	Mtwara	31.2±3.1^a(38)	27.8±1.6^b (35)
Year of birth			
	1997	32.7±1.5^a(11)	29.7±1.9(11)
	1998	36.2±1.7^b(48)	31.6±2.1(43)
	1999	37.6±2.5^b(195)	30.6±1.2(86)
	2000	33.8±2.0^a(69))	28.7±1.6(55)

^{a,b} LSmeans bearing different superscripts along the columns within a specific factor are significantly (P<0.05) different.

4.1.3 Effect of worm burden on growth rate

4.1.3.1 Faecal egg count and packed cell volume on growth rate of goats

Least squares means for the effect of worm burden on growth rate at six and twelve months of age are shown in Tables 8 and 9. Analysis of variance for FEC, PCV and growth rate of goats are shown in Appendix Tables 2 and 3. Results showed that worm burden had significant influence (P<0.05) on growth rate of goats.

At six months of age, increase in PCV and FEC were associated with increase and decrease in growth rate respectively. Goats with highest PCV showed a faster growth rate by (9.6%) compared to their counterparts. However, goats with highest FEC exhibited lower daily gain by 23% compared to those with lowest figures of FEC (Table 8). A similar trend was observed in these parameters at twelve (12) months of age.

Dodoma strain showed the lowest FEC (393.9), highest PCV (24.0) and growth rate (39.2g/day). Mtwara strain had the highest FEC (956.3), lowest PCV (26.2) and growth rate (34.4g). The amount of FEC (521.2), PCV (24.2) and the daily gain (39.8g) for Kigoma strain was between that of the other two strains at six months of age (Table 9).

The differences in FEC, PCV and growth rate between Dodoma and Mtwara strains at one year of age were 258.7, 2.8 and 7.1g/day respectively (Table 9). That is, Dodoma showed the lowest FEC (485.3), highest PCV (26.2) and average daily gain (36.1g) at one year of age, while Mtwara strain exhibited the highest FEC (744.0), the lowest PCV (21.4) and daily gain (29.0g). On the other hand, average daily gain (34.9g/day), FEC (521.2) and PCV (24.2) for Kigoma strain was between that of Dodoma and Mtwara strains (Table 9). However, means for FEC and PCV for Dodoma and Kigoma strains were not significantly (P>0.05) different at six and twelve months of age.

Table 8: Least square means ± se for effect of worm burden (faecal egg count and packed cell volume) on growth rate (g/day) at 6 and 12 months of age

			Age	
Paramter	**Level**	**Unit**	**6 months**	**12 months**
FEC			**LSmeans±se**	**LSmeans±se**
	<700	Epgs	39.2±1.5^{a}	33.0±1.4^{a}
	701-1400	Epgs	36.3±1.6^{b}	31.8±1.1^{a}
	1401-2100	Epgs	32.0±2.1^{c}	27.7±1.8^{b}
	>2100	Epgs	30.8±3.0^{c}	23.4±2.5^{c}
PCV				
	<18	%	32.0±1.6^{a}	29.8±1.5^{a}
	19-25	%	34.6±1.5^{a}	35.8±1.3^{b}
	26-32	%	38.6±3.0^{c}	36.9±0.5^{b}
	>32	%	39.0±2.0^{c}	37.7±1.2^{b}

Table 9: Effect of worm burden on growth rate of each strain of goats

		Parameter			
Age					
	N	**FEC (epgs)**	**PCV (%)**	**Growth rate**	
		LSmeans±se	**LSmeans±se**	**LSmeans±se**	
Overall mean	186	549.2±34.4)	21.9±0.2	38.8±0.3	**6 Months**
Strain					
Kigoma	71	582.7±60.7^{b}	25.1±0.4^{b}	36.8±0.8^{a}	
Dodoma	83	393.9±94.7^{b}	26.2±0.6^{b}	39.2±2.4^{b}	
Mtwara	32	956.3±137.9^{c}	20.9±0.7^{a}	31.4±3.1^{c}	
Overall mean	186	515.1±31.1	23.8±0.3	36.0± 0.1	**12 Months**
Strain					
Kigoma	71	521.2±55.0^{b}	24.2±0.5^{b}	34.9±1.3^{b}	
Dodoma	83	485.3±85.0^{b}	26.2±0.8^{b}	36.1±1.2^{b}	
Mtwara	32	744.0±124.8^{a}	21.4±0.9^{a}	29.0±3.1^{a}	

^{a,b,c} LSmeans bearing difference superscripts along the columns within a specific factor are significantly (P<0.05) different.

4.1.3.2 Regression and correlation coefficients (r) of growth rate, FEC and PCV of goats.

Regression and correlation coefficients between growth rate and FEC, PCV at six months and one year of age are presented in Table 10. Regression analysis showed a negative effect (P<0.001) of FEC (b =-0.49 and –0.46) on growth rate of goats at six and twelve months of age respectively, whereas PCV showed a significantly (P<0.01) positive effect (b=0.54 and 0. 3) on growth rate at 6 and 12 months of age, respectively. There was also a negative correlation coefficient of –0.48 and –0.55 (P<0.001) between FEC and growth rate at six and twelve months of age, respectively. In contrast PCV values showed a significant (p<0.01) positive correlation (r = 0.26 and 0.42) with growth rate at six and twelve months of age respectively.There was a negative correlation (r = -0.48, (P<0.005) and –0.53, (P<0.05) between FEC and PCV at six months and one year of age.

Table 10: Regression coefficients (b) and correlation coefficients (r) of growth rate, FEC and PCV of goats at 6 and 12 months of age

Age	Parameter	b-estimates	Std err	r	Pr>f	n
6 months						
	FEC	-0.49	0.21	-0.48	0.0010	186
	PCV	0.54	0.19	0.26	0.0019	186
12 months	FEC	-0.46	0.13	-0.55	0.0010	186
	PCV	0.30	0.24	0.42	0.0100	186
Correlation coefficient (r) between FEC and PCV						
			Pr>f	n		
6 months		-0.48	(0.005)	186		
12 months		-0.53	(0.05)	186		

Std err = Standard error.

4.1.4 Heritability estimates

4.1.4.1 Heritability estimates of growth rates and weights of goats

Table 11 presents heritability estimates of growth rates of goats between birth and 4 months (pre weaning), 4 - 8 months (post weaning) and 8 - 12 months (yearling); and weights at birth, weaning (4 months), 8 months and 12 months of age. Basing on classification of heritability by Herald (1994), who grouped h2 as low/weak (0 - 0.2), moderate/ medium (0.21 - 0.39) and high/strong (>0.39), heritability was moderate for birth weight, (0.32), pre weaning growth rate (0.34), post weaning growth rate (0.33), and yearling growth rate (0.28), while those of weaning weight (0.4), 8 months weight (0.41) and yearling weight (0.44) were high. Heritability estimates for weights of animals increased with increasing age.

Table 11: Heritability estimates of weights and growth rates at different ages

Trait	h^2	s.e.	n
Weights (kg)			
Birth weight	0.32	0.011	479
Weaning weight	0.40	0.048	333
Weight at 8 months of age	0.41	0.015	223
Yearling weight	0.44	0.020	187
Growth rate (g/day)			
Birth - weaning	0.32	0.013	333
Weaning - 8 months	0.33	0.010	223
8 - 12 months	0.28	0.012	187

4.1.4.2 Heritability estimates for traits of helminth resistance (FEC and PCV)

Heritability estimates of FEC and PCV of goats at six months and one year of age are given in Table 12. Results revealed that heritability for FEC was moderate both at six months (0.3) and twelve (12) months of age (0.35), while estimates for PCV were higher at both ages compared to FEC values.

Table 12: Heritability estimates of FEC and PCV at six and twelve months of age

Trait	h^2	s.e.	n
Faecal egg count (epgs) at 6 months	0.30	0.022	274
Packed cell volume (%) at 6 months	0.41	0.041	274
Faecal egg count (epgs) at 12 months	0.35	0.020	186
Packed cell volume (%) at 12 months	0.43	0.033	185

4.2 Part 2 of the study

4.2.1 Killing out characteristics, physical carcass composition and development of prediction models

4.2.1.1 Killing out characteristics of goats

Results on the effect of strain on killing out characteristics are shown in Table 13. Analyses of variance for the effect of strain on various killing out characteristics of goats are shown in Appendices 6, 7, 8 and 9. Strain showed a significant effect ($P<0.01$) on killing out characteristics. Dodoma strain had the heaviest empty body weight, slaughter weight, carcass weight and higher dressing percentage (DP) compared to those of Mtwara and Kigoma.

For edible non carcass components (expressed as % of slaughter weight), strains exhibited a significant ($p<0.05$) effect on kidney weight, gut fat, feet and tail which were heavier for Dodoma strain followed by that of Mtwara and that of Kigoma goats were the lowest. Other vital organs like gut, pluck, spleen and liver were not significantly ($P>0.05$) different in weight though in absolute terms Dodoma goats had the highest figures.

Table 13: Least squares means for killing out characteristics of three strains of goats

Parameter	Strain				
	Kigoma	Dodoma	Mtwara	SEM	Pr<f
N	9	9	9		
Slaughter wt (kg)	19.19^{a}	25.14^{b}	21.17^{a}	0.001	0.010
Empty body wt (kg)	16.27^{a}	21.41^{b}	16.74^{a}	0.002	0.001
Carcass wt(kg)	9.73^{a}	13.63^{b}	9.82^{a}	0.03	0.002
DP (Cawt/Slwt)	44.72^{a}	49.28^{b}	45.53^{a}	0.001	0.010
Edible non carcass components as % of slaughter weight					
Head	7.6	7.3	7.5	0.09	0.060
Gut	10.0	8.3	9.6	0.10	0.510
Pluck	1.8	1.6	1.8	0.02	0.540
Liver	2.2	2.0	2.1	0.03	0.170
Kidney	0.5^{a}	0.8^{b}	0.4^{a}	0.01	0.010
Spleen	0.3	0.2	0.2	0.920	0.070
Gut fat	0.3^{a}	0.6^{b}	0.5^{b}	0.02	0.050
Hind feet	1.1^{b}	0.32^{a}	1.3^{b}	0.01	0.010
Fore feet	1.4^{a}	1.6b	1.5^{b}	0.03	0.004
Tail	1.1^{a}	1.5^{b}	1.6^{b}	0.04	0.030

^{a,b} LSmeans bearing different superscripts along the rows within a specific carcass parameter are significantly (P<0.05) different.

4.2.1.2 Strain effect on physical carcass composition

Least squares means for the effect of strain on the carcass tissues expressed as percentage of side carcass weight, tissue ratios and total carcass tissues are shown in Table 14. Analysis of variance on the effect of strain on the same components are presented in Appendix Table 8. Strain significantly influenced (P<0.05) physical carcass composition. Dodoma strain had significantly higher (P<0.05) side carcass weight, carcass tissues than that of other strains. The weights of lean and bone were higher (4.26, 1.06 kg) in Dodoma strain compared to Mtwara (3.8, 1.03 kg) and Kigoma (2.99, 0.84 kg), respectively. Strain exhibited no significant (P>0.05) effect on side carcass tissues like lean and bone when they were expressed as the percentage of side carcass weights, though Dodoma strain had the highest figures on such ratios. Mtwara strain had relatively higher total carcass fats than Kigoma and

Dodoma strains. It was also observed that strain had significant influence ($P<0.05$) on the ratios of carcass tissues. Dodoma goats had the highest 5.6, 4.01 and 4.73 lean: fat, lean: bone and lean + fat: bone ratios, followed by Mtwara (4.5, 3.76 & 4.6) and Kigoma (4.46, 3.55 and 4.35), respectively.

Table 14: Least squares means for effect of strain on physical carcass composition

Parameter	Strain				
	Kigoma	Dodoma	Mtwara	SEM	Pr>F
n	9	9	9		
Side carcass wt (kg)	4.35^a	5.98^b	4.85^a	0.330	0.050
Side carcass tissues (kg)					
Lean	2.99^a	4.26^b	3.88^b	0.250	0.040
Bones	0.84^a	1.06^b	1.03^b	0.050	0.050
Fats	0.67^a	0.76^b	0.86^b	0.030	0.030
Ratios of side carcass tissues as % of carcass weight					
Lean	68.43	70.34	69.86	0.010	0.340
Bone	19.75	17.85	18.75	0.010	0.290
Fat	15.54^a	12.56^b	15.52^a	0.003	0.020
Carcass tissue ratios					
Lean: fat	4.46^a	5.60^b	4.50^a	0.280	0.040
Lean: bone	3.55^a	4.01^b	3.76^a	0.140	0.050
Lean + fat: bone	4.35^a	4.73^a	4.60^b	0.150	0.03

^{a,b} Lsmeans bearing different superscripts along the rows within a specific variable are significantly ($P<0.05$) different.

4.2.1.3 Strain effect on weights of side carcass joints and linear carcass measurements

Least squares means of side carcass weights (joints) for each strain are presented in Table 15. Analysis of variance for the effect of strain on carcass joint weights and linear carcass measurements are shown in Appendix Table 9. There was significant ($p<0.05$) influence of strain on weights of various carcass joints when expressed as percentages of slaughter weight. Of the three strains, Dodoma strain had the heaviest ribs, breasts, loin and legs followed by those of Mtwara strain. Kigoma strain had the lowest weights. Mtwara group exceeded all other strains in terms of neck weight.

There was no significant effect ($P>0.05$) of strain on chump weight, though Dodoma group exhibited the highest weight.

Results on the linear carcass measurements showed that strain had significant ($P<0.05$) effect on external body length and hind leg$_1$. Dodoma goats had the longest external body length and hind leg$_1$. Strain had no significant ($P> 0.05$) effect on chest depth, hind leg $_2$, internal body length and hind leg circumference, though Dodoma strain had the longest values.

Table 15: Least squares means for effect of strain on side-carcass joints weights (kg) and linear carcass measurements (cm)

	Strain				
	Kigoma	**Dodoma**	**Mtwara**	**SEM**	**Pr>F**
n	9	9	9		
Neck	0.26^{a}	0.44^{b}	0.55^{b}	0.350	0.04
Ribs	0.98^{a}	1.41^{b}	1.08^{b}	0.090	0.05
Breast	0.29^{a}	0.35^{b}	0.29^{a}	0.020	0.03
Loin	0.46^{a}	0.67^{b}	0.57^{b}	0.050	0.050
Chump	0.35	0.42	0.36	0.030	0.690
Hind leg	1.05^{a}	1.39^{b}	1.15^{b}	0.090	0.02
Foreleg	0.96^{a}	1.30^{b}	0.87^{a}	0.010	0.04
Linear carcass measurements					
EBL	44.93^{a}	48.8^{b}	47.7^{b}	0.040	1.06
IBL	39.28	42.25	41.17	0.110	0.970
CD	25.84	27.78	26.53	0.090	0.063
HL$_1$	30.28^{a}	34.04^{b}	31.94^{b}	0.040	0.880
HL$_2$	16.52	19.03	18.27	0.250	0.350
HLC	31.89	34.23	32.46	0.310	1.080

a,b LSmeans bearing different superscripts along the row within a specific factor are significantly ($P<0.05$) different.

EBL= External body length, IBL = internal body length, CD = chest depth, HL$_1$ = hind leg 1, HL2 = hind leg 2, HLC = hind leg circumference.

4.2.1.4 Prediction equations for carcass weight in simple linear regression using linear body measurements

Regression equations estimating carcass weight using linear body measurements are presented in Table 16. Basing on coefficients of determination (R^2) and significance levels, heart girth predicted carcass weight with highest accuracy (82.4%) followed by height at the rump and height at withers, which had accuracies of 82.2% ($P<0.01$), and 79.3% ($P<0.05$), respectively. External body length predicted carcass weight with the lowest accuracy (73.6%).

Table 16: Simple linear regression equations for prediction of carcass weight using absolute linear body measurements

Dependent variable (Y)	Independent variable (X)	Parameter of estimate				
		a	b	SE	R^2	Pr>F
Carcass weight	HW	-11.49	0.38	0.037	0.793	0.050
	HR	-14.50	0.43	0.038	0.822	0.010
	HG	-18.17	0.42	0.038	0.824	0.020
	EBL	-10.77	0.28	0.030	0.736	0.050
	IBL	-15.17	0.43	0.045	0.780	0.050

HW = Height at withers.

HR =Height at rump.

HG = heart girth.

EBL =External body length.

IBL =Internal body length.

4.2.1.5 Prediction equations of carcass weight by forward multiple regression using linear body measurements of goats

Forward multiple regression equations developed for prediction of carcass weight using linear body measurements (Table 17) show that heart girth measurements can predict carcass weight with an accuracy of about 82.4% ($P<0.05$). When height at the rump was added to the model the coefficient of determination was increased to 88.4%($P<0.05$). When the three variables (HG, HR and HW) were used simultaneously in the model, the coefficient of determination was slightly reduced to 88.3% and the error of estimate was increased.

Table 17: Forward -multiple regression equations for prediction of carcass weight (kg) using linear body measurements (cm)

Parameter	Equation	SE	R^2	Pr>F
HG	-18.17+0.42HG	0.038	0.824	0.02
HG+HR	-18.37+0.23HG+0.22HR	2.07	0.884	0.05
HG+HR+HW	-17.93+0.22HG+0.16HR+0.05HW	2.14	0.883	0.05

HG = Heart girth

HR =Height at rump

HW = Height at withers

4.2.1.6 Prediction of carcass tissues: lean (Y_1), bone (Y_2) and fat (Y_3) in simple linear regression equation using weights of various carcass joints

Simple linear regression equations for estimating side carcass tissues (lean, bone and fat) using joint weights are presented in Table 18.

Basing on coefficients of determination (R^2), standard errors and significance levels, it can be said that foreleg predicted best the total carcass lean followed by rib and loin. Neck, breast, chump and hind leg had no significant ($P>0.05$) influence on total lean weight of goats. Ribs highly ($P<0.05$) predicted the total carcass bones followed by foreleg and loin. On overall, rib joint accounted for 89%, 87% and 69% of total variations in the carcass lean, bone and fat, respectively. On the other hand, neck, breast and chump did not estimate bones accurately ($P>0.05$). It was also observed that rib, breast, foreleg predicted total carcass fat better ($P<0.05$). The hind leg, chump and neck poorly estimated ($P>0.05$) total fat.

Table 18: Simple linear regression equations for prediction of absolute carcass tissue, lean (Y_1) bone (Y_2) and fat (Y_3) using weights of various carcass joints (kgs)

		Parameters				
Independent variable X	**Dependent variable Y**	a	b	SE	R^2	Pr>F
Neck	Y_1	1.32	5.78	0.72	0.41	0.140
	Y_2	0.507	1.11	0.15	0.54	0.130
	Y_3	0.08	0.08	0.03	0.41	0.201
Rib	Y_1	0.54	2.60	0.17	0.89	0.040
	Y_2	0.347	0.51	0.04	0.87	0.050
	Y_3	-0.029	0.39	0.04	0.59	0.022
Breast	Y_1	0.815	8.94	1.76	0.69	0.054
	Y_2	0.465	1.54	0.39	0.45	0.030
	Y_3	1.33	0.29	0.72	0.70	0.020
Loin	Y_1	0.682	5.26	0.44	0.84	0.042
	Y_2	0.419	0.95	0.12	0.69	0.050
	Y_3	0.018	0.74	0.1	0.65	0.050
Chump	Y_1	0.027	8.80	1.13	0.69	0.055
	Y_2	0.348	1.58	0.26	0.48	0.023
	Y_3	-0.148	1.18	0.23	0.36	0.860
Hind leg	Y_1	0.901	2.17	0.34	0.59	0.010
	Y_2	0.437	0.40	0.74	0.53	0.018
	Y_3	0.387	0.31	0.06	0.48	0.622
Fore leg	Y_1	0.235	3.57	0.29	0.92	0.044
	Y_2	0.242	0.65	0.06	0.78	0.030
	Y_3	0.101	0.49	0.06	0.68	0.046

4.2.1.7 Prediction equations of carcass tissues in forward multiple regression using carcass joints

Forward multiple regression equations for prediction of carcass tissues using carcass joints (neck, ribs, breast, loin, chump, hind leg, fore leg) are presented in Table 19. Results show that foreleg was the best predictor of lean ($R^2 = 0.92$). When rib was added to the model, the coefficient of determination increased to 0.95

When loin was added to the model a further improvement in prediction of lean carcass content was observed. On the other hand rib was the best predictor of carcass bone (R^2 = 0. 87). On adding fore leg to the model, the coefficient of determination was increased (R^2 = 0.88). Rib also predicted fat much better (0. 80%) than other joints. When breast was included in the model, the coefficient of determination was reduced to 79%.

Table 19: Forward multiple regression equations for estimation of carcass tissues: lean (Y_1), bone (Y_2) and fat (Y_3) using carcass joints (kg)

Tissue (Y)	Parameter (x)	Equation	SE	R^2	Pr> F
Y_1	Fleg	0.235+3.56fleg	0.290	0.92	0.023
	Fleg+rib	-0.079+2.13Fleg	0.690	0.95	0.030
	Fleg+rib+loin	-0.045+1.68Fleg+0.78rib+1.481oin	1.480	0.96	0.024
Y_2	Rib	0.347+0.051 Rib	0.038	0.87	0.051
	Rib+Fleg	0.292+0.39 Rib+0.18 Fleg	0.055	0.88	0.050
Y_3	Rib	-0.029+0.39 Rib	0.040	0.80	0.040
	Rib+Breast	-0.074+0.35 Rib+0.3Breast	0.057	0.79	0.025

Fleg = Fore leg

4.2.1.8 Estimation of carcass tissues, lean (Y_1), bone (Y_2) and fat (Y_3) in simple linear regression using carcass, empty and slaughter weights

Regression equations for estimating total carcass tissue weights using empty body weight; slaughter and carcass weights are shown in Table 20. Slaughter, empty and carcass weights poorly estimated the total fat weight ($P>0.05$). On the other hand, carcass weight was the best and most accurate (R^2 =98%) in estimating carcass lean. Empty body weight predicted total lean with the lowest accuracy (73%), whereas slaughter weight better predicted bones (R^2 = 89%) compared to the other weights.

Table 20: Simple linear regression equations for prediction of absolute carcass tissues (kg): lean (Y_1), bone (Y_2) and fat (Y_3) using carcass, empty and slaughter weights (kg)

Variables		Parameters				
Independent variable X	**Dependent variable Y**	**a**	**b**	**SE**	**R^2**	**Pr>F**
Slaughter wt	Y_1	-0.745	0.196	0.008	0.95	0.02
	Y_2	0.108	0.037	0.003	0.89	0.05
	Y_3	-0.193	0.028	0.003	0.76	0.04
Carcass wt	Y_1	-0.202	0.370	0.008	0.98	0.02
	Y_2	0.023	0.069	0.005	0.87	0.02
	Y_3	-0.106	0.052	0.006	0.77	0.04
Empty body wt	Y_1	-0.286	0.210	0.020	0.77	0.05
	Y_2	0.199	0.040	0.005	0.73	0.05
	Y_3	-0.286	0.030	0.004	0.64	0.04

CHAPTER FIVE

5.0 DISCUSSION

5.1 Part I of the study

5.1.1 Effect of sex, birth type, strain and year of birth on growth rate

In the present study, the overall mean growth rates of goats between birth and four, birth and eight, birth and twelve, four and eight, eight and twelve months of age were 38.5, 35.9, 29.8, 35.3 and 29.0/day, respectively. These results were more or less equal to values reported by Karua and Banda (1992) who observed average daily gains of 44 and 25g per day for pre weaning and post weaning phases of kids of various indigenous tropical goat breeds.

Sex had significant influence ($P<0.05$) on growth rate of goats. Male kids grew faster than females at four and eight months of age. This trend was also reported by Kyomo (1978) at four months of age and Rhind (1992); Mourad (1993) and Assenga (1997) at 8 months of age. This could be attributed to differences in cell muscle numbers, which is higher in males. However it was contrary to findings reported by Abunie (1992) who indicated that female kids were superior to males at 8 months of age. At twelve months of age, no significant difference on growth rate was observed between male and female kids, though males had higher daily gain. This is not in agreement with Abunie (1992) who showed that females were heavier than males.

Birth type has been reported by Kyomo (1978) and Hof *et al.* (1984) to have an influence on growth rate at various phases of growth. In the present study, there was a significant effect of birth type between birth and four months of age; single kids had higher growth rate compared to multiples. This agrees with the findings by Prakash and Singh (1989) who reported higher growth rate of single kids during pre-weaning growth phase. However, average daily gains of kids did not differ significantly at eight and twelve months of age, though single kids had higher daily gain than multiples. These results supported findings reported by Kyomo (1978); Das and Sendalo (1990) and Abunie (1992) who observed that, after weaning the differences in growth rates between single kids and multiples disappeared. This could be attributed to decrease in maternal influence on growth rate of kids after weaning. It could also be attributed to compensatory growth in twins after being exposed to pasture feeding.

Strain differences exhibited a significant influence ($P<0.05$) on growth rate at 4, 8 and 12 months of age. In all periods, Dodoma strain showed the highest growth rate followed by Kigoma and lastly by Mtwara strain. This could be attributed to relatively higher feed conversion efficiency of Dodoma strain compared to other strains under similar grazing management practices.

Year of birth had no significant effect on growth rate at four and twelve months of age. Probably, this insignificant difference in growth rate could be attributed to similarities in management practices (free grazing) of animals across the four years (1997-2000) of study. However, year to year variations were observed to be significant ($P<0.05$) at 8 months of age. These findings concur with Abunie (1992) and Nagpal and Chawala (1995). The reasons for these differences could be variations in managerial and climatic factors such as weather changes which might have influenced feed availability and prevalence of diseases.

5.1.2 Effect of worm burden on growth rate of goats

5.1.2.1 Association between FEC, PCV and growth rate

Results revealed that worm burden had significant effect on growth rate at six and twelve months of age as reflected by indicators of helminth infection (i. e FEC and PCV). Increase in PCV and FEC were associated with increase and decrease in growth rate respectively. These observations support the findings by Gimbi (2000) who observed decrease in growth rate with increasing FEC and decreasing levels of PCV. The strains of goats (Dodoma and Kigoma) which had highest PCV and lowest FEC had higher growth rates than the Mtwara strain which had the lowest PCV and highest FEC. This finding conforms to that reported by Bisset *et al.* (1996) who observed that animals with high resistance to gastrointestinal nematodes exhibit higher growth rate and carry fewer worms than susceptible ones.

Susceptibility to helminths as measured by FEC and PCV parameters demonstrated that there was a significant ($P<0.05$) difference among strains in their ability to withstand worm infestations. However, Dodoma and Kigoma strains did not differ ($P<0.05$) significantly in terms of resistance to gastrointestinal nematodes, but both of them were more resistant than the Mtwara strain.

The two groups of goats (Dodoma and Kigoma) have been reported to have insignificant genetic differences as revealed by RAPDs polymorphism (Challya *et* *al.*, 1997), but the two strains are genetically different from the Mtwara strain (Challya, 1998). This study conforms to that reported by Keyyu (1998) who observed the same trend of susceptibility to helminthosis in the same strains of goats. This study has also shown that resistance to helminth parasites was associated with favourable production parameters (like high growth rate). In terms of increasing susceptibility to helminths, the three strains were ranked as Dodoma, Kigoma and Mtwara. The lowest growth rate of Mtwara strain could probably be attributed to "plasma loosing enteropathy" (i.e. loss of plasma fluids and protein by leaking through the damaged epithelial mucosa), low genetic potential in average daily gain and withstanding helminth infestations. The normal range of PCV in goats is 20% to 38% (Fascar, 1986). This is in agreement with the results of the present study where PCV ranged from 20.9% to 26.2%.

5.1.2.2 Regression coefficients (b) of growth rate on FEC and PCV

Regression analysis results indicated a negative effect of FEC on growth rate at six and twelve months of age, which implied that an increase in FEC was associated with a decrease in growth rate. This could be attributed to damage of gut tissues by helminths, which impaired live weight gain. This is in line with the findings by Baker (1995) who reported that gastrointestinal nematodes like *Haemonchus spp, Cooperia spp and Trichostrongylus spp* can cause impaired daily gain since they feed on plasma fluids and damage the epithelial mucosa leading to malabsorption and loss of plasma and protein required for growth. On the other hand, positive response of PCV on growth rate indicates that PCV is directly associated with increase in growth rate of animals. The level of PCV reflects the level of immune response which the animal possesses against a certain nematode infection.

5.1.2.3 Correlation coefficients between FEC and PCV at six and twelve months of age

This study showed a negative correlation coefficient between FEC and PCV at six and twelve months of age. That is, an increase in PCV was associated with a decrease in FEC. These findings are in line with those reported by Miller *et al.*(1998) and Keyyu (1998) who showed that PCV and FEC were inversely related to infections by gastrointestinal helminths like nematodes. Similarly, Bahirathan *et al.* (1996) reported an increase in FEC with concomitant reduction in PCV in Sulfok lambs following naturally acquired nematode infection. This reflects mobilization of blood and protein into repair of damaged gut tissues (Miller *et al.*, 1998). Also blood sucking parasites like *Haemonchus contortus* cause anaemia which is reflected in reduced PCV or blood level and reduced live weight gain. Animals which are able to maintain high PCV and lower FEC during gastrointestinal nematode infection where *Haemonchus contortus* is dominant have been considered as resistant compared to animals that cannot (Mugambi *et al.*, 1997; Keyyu, 1998). Dodoma strain had the highest PCV and lowest FEC than the rest of the strains; this could imply that the Dodoma goats are genetically most resistant to helminth infection.

5.1.3 Correlation coefficients between growth rate, faecal egg count and packed cell volume at six and twelve months of age

In the present study, a significant ($P<0.05$) negative correlation was observed between growth rate and FEC at six month (-48%) and one year (-17%) of age. Working on the pathophysiological effect of helminths, Hansen and Perry (1994b), Coop and Holmes (1996) and Knox and Steel (1997), reported that larvae and adult nematodes cause damage to gastrointestinal mucosa, poor mobilization and utilization of nutrients leading to depressed growth rate because protein and energy are diverted away from vital processes into repair of the damaged gut. This could be the reason for inverse relationship observed between FEC and growth rate of animals. Positive correlation between PCV and growth rate observed at six (6) and twelve (12) months of age indicates that an increase in PCV is associated with increase of immune response against parasite infections, which actually leads to increase in gain in live weight.

5.1.4 Heritability estimates

5.1.4.1 Heritability estimates for growth rate and weights at different ages

Results on heritability estimates of growth rates and weights at different ages revealed that traits which had moderate heritability were birth weight, pre-weaning growth rate, post-weaning growth rate and yearling growth rate (Table 11). For these traits, heritability ranged from 0.28 to 0.38 indicating that non-genetic or environmental factors play a greater role in the overall performance. Several workers (Herald, 1994; Falconer and Mackay, 1998) have reported that for traits which are affected by moderate additive gene action (moderate h^2), selection and cross breeding respond moderately. Therefore, to achieve high growth rate in these animals, combined improvement methods viz ample nutrition and balanced diet, selection, cross breeding and bio-molecular techniques should be applied.

Traits that had relatively high heritability were weaning weight, post weaning weight and yearling weight. This indicates that genetic and non-genetic factors contribute almost equally in conferring production performance of these traits. Traits with relatively high heritability or additive gene variance have been viewed to respond highly to selection and cross breeding. In this study therefore, improvement strategies for these traits through cross breeding and selection should be supported by proper management practices. However, in developing improvement strategies for these animals, it should born in mind that production performance of animals can be affected by genotype x environment interaction. That is, superior individuals in a particular environment cannot necessarily be superior in another environment. Dalton (1987) contented that Hereford (*Bos taurus)* and Brahman (*Bos indicus*) performed differently when they were tested for growth rate in two contrasting environments, namely, temperate climate with ample nutrition and disease free atmosphere, and tropical climate with endemic diseases and poor nutrition. Hereford failed to perform well in tropics (because of diseases, poor nutrition and heat stress), whereas Brahman performed well in both environments. He further envisaged that, it is better to select and breed animals in the environments in which they could perform highly.

Heritability increased with increasing age of animals. This could be attributed to decrease in environmental variations (including maternal) with increasing age. This concurs with the findings reported by Herald (1994) who envisaged that there is a lot of environmental variations in early life (i.e. rearing environment) which often result in low heritability estimates, but with increasing age such variations cease or decrease. The author also reported that additive genetic components tend to increase with increasing age of animals. This factor also contributes to an increase in the estimated values.

5.1.4.2 Heritability estimate for traits of helminth resistance (FEC and PCV)

Packed cell volume and FEC are traits of importance in measuring resistance of animals to helminth infection.

Results of this study indicate that heritability estimate of FEC was moderate at six and twelve months of age (Table 12). The observed heritabilities were high for PCV at six and twelve months of age, that is 0.41 and 0.43, respectively. These findings concur with those reported by Baker *et al.* (1991) who reported estimates of heritability for PCV ranging from 0.4 to 0.45 in pre-weaning and post-weaning growth phases of goats. By considering both PCV and FEC heritability figures obtained in the present study, it can be said that the animals evaluated under this study are in a good position to withstand worm infestation provided other management practices are good. It appears from this study that FEC and PCV are efficient selection criteria to improve worm resistance through selection of resistant hosts.

5.2 Part II of the study

5.2.1 Killing out characteristics, physical carcass composition and prediction models

5.2.1.1 Strain effect on killing out characteristics of goats

Dodoma strain had the highest ($P<0.05$) dressing percentage (DP), empty body weight and carcass weight (when expressed as percentage of slaughter weight) compared to Kigoma and Mtwara strains. This could probably be a result of better efficiency of feed conversion for Dodoma strain than the rest of the animals under the same free grazing management practices.

The observed dressing percentages of 49,3%, 47.7% and 45.5% for Dodoma, Kigoma and Mtwara strains respectively conforms to the values reported by Hutchson (1964) which ranged from 46.5% to 55.5%. However, Kitalyi (1982) and Assenga (1997) reported lower dressing percentages 32 to 39%and 39% to 43% respectively, compared to the values observed in the current study. The differences in these reported values could, probably, be due to variation in age, sex and slaughter conditions. DP is affected by level of feeding, procedure of weighing the animal, type of diet, and degree of fatness and dressing conditions (Kyomo, 1978). The proportion of gut can also influence DP positively or negatively (Assenga, 1997).

5.2.1.2 Strain effect on physical carcass composition of goats

Table 14 revealed significant ($P<0.05$) influence of strain on carcass composition and carcass tissue ratios. Dodoma and Kigoma had the highest and lowest weights, respectively, and Mtwara being in between. Lean, bone and fat as percentage of side carcass weight ranged from 68.4% to 70.3%; 17.8% to 19.7% and 12.6% to 15.5%

respectively. These findings conform to those reported by Kyomo (1978) who observed proportions of lean, bone to range from 68 % to 73% and 6% to 18.7%; except for fat percentages which were low (7% to 8.1%). However, the values for the current study are very dissimilar to the proportion composition of lean, bone and fat of 62.0, 19.96 and 17.7% reported by Mavoa (1980) and 63, 18.5,and 14% observed by Kitalyi (1982). The difference between the values observed in the present study from those reported earlier could be attributed to differences in live weight, age and breed/strains of the used animals.

It has been shown that the quantity and distribution of lean, fat and bone are of great importance to both producers and consumers as they determine the economic value of the animal (Simm, 1992; Kirk *et al.*, 1996). Usually, fat content in goat carcasses older than 9 months varies from 6 to 15%. The goats in the present study fall under animals with desirable carcasses because they had the optimal amount of fats, minimum bone and slightly maximum lean. This concurs to that reported by Berg and Butterfield (1976) who contented that, a superior carcass is one which consists of maximum amount of muscle, a minimum of bone and an optimal of fat.

5.2.1.3 Strain effect on side carcass weights and linear carcass measurements

From Table15 it can be seen that strain had significant effect ($P<0.05$) on ribs, neck, breasts, loin and leg. Dodoma goats had the heaviest weights in almost all joints compared to Mtwara and Kigoma goats, respectively. The differences could be attributed to differences in genetic make-up and feed conversion efficiency. Dodoma group could probably have higher feed conversion efficiency than the rest under similar management practices.

Observations on linear body measurements revealed that strain exhibited significant influence ($P<0.05$) on internal body measurements and hind leg. Strain showed small and generally insignificant effect ($P>0.05$) on the rest of the linear body measurements, though Dodoma had the highest weights over Mtwara and Kigoma strains. The differences could be attributed to genetically inherent characteristics of the animals under study. Dodoma strain could probably have genetically longer internal body length compared to the other two strains of goats.

5.2.1.4 Prediction equations for carcass weight in simple linear regression equations using linear body measurements

Heart girth predicted carcass weight with the highest accuracy followed by height at rump and height at withers. That is, in comparison with all other variables, heart girth showed a comparatively better prediction accuracy and low error of estimate of carcass weight than the rest of the linear body measurements. These observations support the findings by Berhanu *et al.* (1992) and Madubi (1997) who reported that heart girth was the best predictor of body weights. However, contradicting findings have been reported by Hassan and Ciroma (1990) who contented that body length had the greatest accuracy of predicting such parameters.

5.2.1.5 Prediction equations for carcass weight in forward multiple regression equations using linear body measurements

In the present study, increase in coefficient of determination when height at rump was included in the model indicated that carcass weight could be estimated better when the two linear body measurements are used simultaneously in a multiple regression. Hence it is tempting to make a general speculation that inclusion of two linear body measurements (HG and HR) in the multiple regression equation can sufficiently predict carcass weight.

5.2.1.6 Prediction equations of carcass tissues in simple linear regression equations using weights of various carcass joints

Regression equations developed for prediction of carcass tissues on side carcass joints (Table 18) showed that fore leg joint was the best and most accurate (82.4%) in predicting the total lean followed by rib (82.2%) and loin (79.3%) joints. Generally, the foreleg weight accounted for 92%, 78% and 68% of the total variations in the carcass lean, bone and fat (R2) respectively. This finding conforms to that reported by Daka (1987) who showed that the fore leg joint is the most accurate in estimating the total carcass lean. Rib joint best estimated carcass bone and fat. These observations concurred to that reported by Berg and Butterfield (1976) who found out that bone and fat tissues were most accurately predicted by rib joint. However, these findings are not in accordance with that reported by Daka (1987), who showed that neck joint best estimated the total carcass bone. The differences could have emanated from age and breed differences of the animals used in the study, i.e. Daka (1987) used sheep while the current study used goats.

5.2.1.7 Prediction equations of carcass tissues in forward multiple regression equations using weights of various carcass joints

In the current study, increase in coefficient of determination (Table 19) when rib and loin; fore leg were added to lean and bone models, respectively, indicated that a combination of carcass joints could be used in a multiple regression equation to improve the accuracy of predicting carcass tissues. But, decrease in coefficient of determination when breast was added to fat model indicated that one variable could better estimate carcass fat. This is in accordance to the findings by Valdez *et al.* (1982) and Hassan and Ciroma (1990) who reported that individual or combined body measurements could be used for predicting carcass components.

5.2.1.8 Prediction equation for carcass tissues in linear regression equations using empty body weight, carcass and slaughter weights

Linear regression equations developed for prediction of carcass tissues using empty body weight, slaughter weight and carcass weight (Table 20) showed that carcass weight was the best and most accurate variable in predicting the total carcass lean compared to slaughter weight and empty body weight. However, more investigation is required as information obtained from the present study was from few numbers of goats per strains. Thus caution is needed to make strong recommendations.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

From the results of the present study, the following conclusions can be made: -

1. Dodoma strain showed superiority in growth rate, resistance to worm burden, carcass weight and composition compared to Kigoma and Mtwara strains. This indicates that it could be preferred for use in improvement programmes like cross breeding, selection and genetic manipulation at molecular level.

2. Moderate and high heritability estimates obtained in this study indicates that the traits evaluated in this study could be improved through selection.

3. In estimating carcass weight from linear body measurements, heart girth was the best predictor variable ($P<0.05$, $R^2 = 82.4\%$). The best result was obtained when heart girth and height at rump were used together ($P<0.05$, $R^2 = 88.4\%$) in the model.

4. In the forward multiple regressions analysis for prediction of carcass weight using linear body measurements the following carcass weight prediction equations were developed:

Carcass weight = $-18.17 + 0.42$ HG ($P<0.05$, $R^2 = 82.4\%$)

= $-18.37 + 0.23$ HG + 0.22 HR ($P<0.05$, $R^2 = 88.4\%$)

5. Prediction of carcass tissues using carcass joints of side carcass weights showed that foreleg was the best predictor of carcass lean ($P<0.05$, $R^2 = 92\%$). In the estimation of other carcass components, rib joint was the best predictor of carcass bone ($P<0.05$, $R^2 = 87\%$) and fat ($P<0.05$, $R^2 = 69\%$).

6. In forward multiple regression analysis, the following equations to predict carcass tissues in goats using carcass joints were developed:

Carcass lean = 0.235 + 3.56 Foreleg ($p<0.001$, $R^2 = 92\%$)

= -0.079 +2.13 Foreleg + 1.19 Rib ($P<0.003$, $R^2 = 95\%$)

= -0.045 + 1.68 Foreleg +0.87 Rib + 1.48 Loin ($P<0.001$, $R^2 = 96\%$)

Carcass bone = 0.34 + 0.39 Rib ($P<0.001$, $R^2 = 87\%$)

Carcass fat = -0.0292 + 0.391 Rib ($P<0.0001$, $R^2 = 80\%$)

7. Dodoma strain had the lowest worm load (FEC), highest PCV and growth rate than the rest of the strains under study. Thus, Dodoma strain is more resistant to helminth infestation and it can, therefore, be used in genetic improvement programmes such as breeding for helminth resistance.

6.2 RECOMMENDATIONS

1. The present study has contributed to the knowledge of heritability estimates of three stains of goats in Tanzania. However, the data used to estimate heritability at one year of age were rather few to make them reliable. Hence, more studies are

needed to be able to quantify heritabilities of growth rate, worm burden (FEC and PCV) at one year of age.

2. This study has contributed to the knowledge of strain effect on physical carcass composition of three strains of Tanzania goats. There is a need for further studies within the Dodoma group and between other strains to see whether the superiority it expressed over the two strains is verified over other Tanzanian strains.

3. It has been shown that Dodoma and Kigoma strains were equally resistant to helminth infections and that both of them were more resistant than Mtwara strain. Thus, there is a need to know if the higher resistance to internal parasites is associated with resistance to other prevalent diseases under Tanzania conditions. Hence, in order to reach strong conclusions, further studies on resistance to diseases are required.

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APPENDICES

Appendix Table 1: ANOVA for effect of sex, birth type, strain and year of birth on growth rate of goats between birth and 4, birth and 8, birth and 12, 4 and 8, 8 and 12 months of age

Age	Source	DF	Mean square	Pr>f	Remarks
Birth-4 months					
	Sex	1	247.4	0.001	*
	Birth type	1	77.2	0.049	*
	Strain	2	189.3	0.001	**
	Year of birth	3	231.4	0.211	NS
	Sex * birth type	1	158.9	0.001	
	Strain*year of birth	4	160.5	0.205	NS
	Residual	325	109.1		
Birth-8 months					
	Sex	1	714.2	0.010	*
	Birth type	1	87.8	0.430	NS
	Strain	2	155.8	0.021	*
	Year of birth	3	162.0	0.050	*
	Sex*birth type	4	158.9	0.010	*
	Strain*year of birth	1	204.1	0.360	NS
	Residual	325	98.3		
Birth-12 months					
	Sex	1	480.8	0.110	NS
	Birth type	1	86.7	0.090	NS
	Strain	2	249.3	0.005	**
	Year of birth	3	130.2	0.090	NS
	Sex * birth type	1	158.9	0.047	*
	Strain * year of birth	4	366.0	0.074	NS
	Residual	325	115.6		
4 -8 months					
	Sex	1	381.0	0.041	*
	Birth type	1	98.4	0.710	NS
	Strain	2	122.3	0.001	*
	Year of birth	3	92.6	0.005	**
	Sex * birth type	1	199.3	0.025	*
	Strain * year of birth	4	238.6	0.090	NS
	Residual	215	86.4		
8- 12months					
	Sex	1	766.2	0.110	NS
	Birth type	1	203.9	0.076	NS
	Strain	2	305.2	0.010	*
	Year of birth	3	125.1	0.070	NS
	Sex * birth type	1	269.6	0.038	*
	Strain * year of birth	4	396.4	0.306	NS
	Residual	176	120.5		

Appendix Table 2: ANOVA for effect of worm burden (FEC and PCV) on growth rate of goat strains at six months of age with birth weight as covariate

		Growth rate		
Source	DF	Mean square	Pr>f	Remarks
Birth weight	1	262.9	0.076	
Strain	2	340.6	0.017	**
Sex	1	5137.5	0.0001	***
Birth type	1	777.7	0.0025	***
Year of birth	3	134.8	0269	NS
Faecal egg count	3	346.3	0.006	**
Packed cell volume	3	2110.6	0.001	***
Residual	173	82.6		

Appendix Table 3: ANOVA for effect of worm burden (FEC and PCV) on growth rate of goat strains at twelve months of age with birth weight as covariate

		Growth rate		
Source	DF	Mean square	Pr>f	Remarks
Birth weight	1	31.8	0.4560	
Strain	2	199.2	0.0330	*
Sex	1	1570.0	0.0002	**
Birth type	1	47.9	0.4750	NS
Year of birth	3	241.4	0.3590	NS
Faecal egg count	3	288.5	0.0010	***
Packed cell volume	3	325.1	0.0010	***
Residual	173	145.3		

Appendix Table 4: ANOVA for regression of growth rate on FEC and PCV at six months of age

		Growth rate		
Source	DF	Mean square	Pr>f	Remarks
Strain	2	663.1	0.010	**
Sex	1	3343.1	0.001	***
Birth type	1	223.7	0.060	NS
Year of birth	3	137.4	0.320	NS
Faecal egg count	1	308.9	0.004	**
Packed cell volume	1	275.9	0.001	***
Residual	174	82.6		

Appendix Table 5: ANOVA for regression of growth rate on FEC and PCV at twelve months of age

		Growth rate		
Source	**DF**	**Mean square**	**Pr>f**	**Remarks**
Sex	1	263.4	0.88	NS
Birth type	1	92.3	0.09	NS
Strain	2	205.8	0.02	*
Year of birth	3	247.6	0.08	NS
Faecal egg count	1	831.7	0.0010	***
Packed cell volume	1	131.2	0.010	**
Residual	174	145.3		

Appendix Table 6: ANOVA for killing out characteristics of goats by strains

Source	**DF**	**Mean squares**			
		Slaughter weight (kg)	Empty body weight (kg)	DP%	Carcass weight (kg)
Strain	2	33830.1** (0.01)	446994.4*** (0.001)	11362.1** (0.01)	22170.5** (0.002)
Residual	23	11069.2	3288470.2	55123.3	38539.7

DP = dressing percentage (i.e. slaughter weight / carcass weight)

Numbers in Parentheses are significance levels.

Appendix Table 7: ANOVA for edible non -carcass components

Variable	Source	DF	Mean Squares	Pr>f	Remarks
Head weight			387244.4		
	Strain	2	1883.3	0.06	NS
	Residual	23			
Gut weight					
	Strain	2	74014.8	0.51	NS 7
	Residual	23	9150.0		
Pluck weight					
	Strain	2	5576	0.54	NS
	Residual	23	1358		
Live weight					
	Strain	2	11511.2	0.6	NS
	Residual	23	3521.9		
Kidney weight					
	Strain	2	16192.6	0.01	**
	Residual	23	1562.9		
Spleen weight					
	Strain	2	11.8	0.07	NS
	Residual	23	114.2		
Hind feet weight					
	Strain	2	16103.7	0.01	**
	Residual	23	1566.7		
Fore feet weight					
	Strain	2	5486.2	0.004	**
	Residual	23	2429.6		
Tail weight					
	Strain	2	533	0.03	*
	Residual	23	185.2		

Appendix Table 8: ANOVA for side physical carcass composition as affected by strain

Variable	Source	DF	Means Square	Pr>f	Remarks
Lean weight					
	Strain	2	6532.4	0.005	**
	Residual	23	23946.3		
Bone weight					
	Strain	2	896.5	0.005	**
	Residual	23	34046		
Fat weight					
	Strain	2	25160.	0.004	**
	Residual	23	1357.9		
Lean: side carcass weight					
	Strain	2	103806.8	0.3	NS
	Residual	23			
Bone: side carcass weight					
	Strain	2	5726.5	0.3	NS
	Residual	23	290.1		
Fat : carcass weight					
	Strain	2	321.5	0.004	**
	Residual	23	38.8		
Lean: bone ratio					
	Strain	2	321.5	0.004	**
	Residual	23	39.2		
Lean: fat ratio					
	Strain	2	4806177.8	0.04	*
	Residual	23	699893.5		
Lean+ fat: bone ratio					
	Strain	2	164.2	0.04	
	Residual	23	219.3		

Appendix Table 9: ANOVA for side-carcass joints' weights (kg) and linear carcass measurements (cm)

Variable	Source	DF	Mean squares	Pr>f	Remarks
Neck weight					
	Strain	2	130119.6	0.04	*
	Residual	23	243307.1		
Rib weight					
	Strain	2	38016.3	0.004	**
	Residual	23	70137.9		
Breast weight					
	Strain	2	1180.7	0.04	*
	Residual	23	4133.3		
Loin weight					
	Strain	2	34018.1	0.05	*
	Residual	23	20283.5		
Chump weight					
	Strain	2	4041.6	0.07	NS
	Residual	23	6200.1		
Hind leg weight					
	Strain	2	1864.3	0.004	**
	Residual	23	8933.5		
Fore leg weight					
	Strain	2	11926	0.001	***
	Residual	23	33970.4		
External body length					
	Strain	2	27.8	0.05	*
	Residual	23	10.3		
Internal body length					
	Strain	2	16.5	0.5	NS
	Residual	23	10.3		
Chest depth					
	Strain	2	6.8	0.09	NS
	Residual	23	3.5		
Hind leg 1					
	Strain	2	62.6	0.04	*
	Residual	23	171.6		
Hind leg 2					
	Strain	2	25.6	0.07	NS
	Residual	23	11.2		
Hindleg circumference					
	Strain	2	41.3	0.3	NS
	Residual	23	253.3		