ALLOMETRIC GROWTH COEFFICIENTS AND PARTITIONING OF FAT DEPOTS IN INDIGENOUS ETHIOPIAN MENZ AND HORRO SHEEP BREEDS

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Abstract

A total of 146 Menz and Horro lambs of both sexes were serially slaughtered and dissected at 5 different stages of growth (i.e. at 1, 3, 6, 9 and 12 months of age) to define the pattern of growth and partitioning of fat among body depots of indigenous Ethiopian Menz and Horro sheep breeds. The GLM procedure of SAS and an allometric growth equation were used to assess the effects of various factors on the growth of body depots and to estimate rates of growth relative to Total Body Fat (TBF) and Empty Body Weight (EBW), respectively. Results obtained showed that the growth of carcass fat (CF), Non-Carcass Fat (NCF) and Tail Fat (TF) are significantly affected by the genotype ($P<0.0001$) and stage of growth ($P<0.0001$) of lambs. Except for CF growth of both NCF and TF were also significantly affected ($P<0.001$ and $P<0.05$, respectively) by the sex of the lamb and the season in which lambs were born. Menz sheep deposited more fat into CF and less in NCF depots as compared with Horro sheep. Females of both breeds tended to deposit more fat intra-abdominally than male lambs. In both breeds, the highest allometric growth coefficient obtained for TF and the lowest for NCF indicate that the former is a late developing while the later is an early maturing depot fat.

1. Introduction

The growth of fat in domestic animals is an extremely important part of the total growth process from several points of view (Berg and Butterfield 1976). The major biological role of fat is undoubtedly to serve as an energy store, providing a survival buffer against periodic food scarcity such as in draught and winter conditions. In this regard, mobilization of body fat during prolonged periods of underfeeding is a well-known phenomenon. Crampton and Harris (1969) and also several others reported that during unfavorable seasons when exogenous energy is in short supply, animals tend to rely on the energy stored in the adipose tissues for their survival.

The fact that fat depots change with, and partially controls, the various productive functions such as lactation, fattening, work and growth in animals is widely reported. In most systems of sheep production, ewes lose body weight in early lactation and Sykes (1974) reported that under hill conditions ewes can almost totally deplete their body fat reserves by mid lactation. There are several other examples of strategic mobilization of body reserves to support vital body physiological activities but there is a paucity of information on the type and site of depot mobilization. As a major carcass tissue, body fat depots also affect the meat production industry, including feeding, deciding on the optimum slaughter weight and grading of the carcass and meat quality (Mtenga et al. 1994).

Fat is undoubtedly the most variable tissue in the carcass and it varies not only in total amount but its partitioning among the various depots alters markedly throughout growth. The pattern of this growth and distribution of fat within the animals body has its own vital physiological significance and it is an area demanding extensive investigation. This is mainly because: a great deal of the relative carcass value of different types of animals depends on the manner in which they partition fat among body depots and particularly the survival of an animal during the dry season and/or at times of energy deficiency depends on the extent to which they deposit their body fat reserves in readily utilizable depots. The sequence of growth and partition of fat among body depots, therefore, reflects the relative importance of each in serving the animal needs and also the market value of the carcass. Thus, defining the pattern of growth and distribution of fat in small ruminants is essential to an understanding of the dynamics of body and carcass composition

changes associated with production, marketing and survival during nutritionally unfavorable seasons. However, not much is known about tropical sheep breeds and particularly information on breed comparison studies is scarce.

The main objective of this study was to define the pattern of growth and partitioning of fat among body depots of in indigenous Ethiopian Menz and Horro sheep breeds.

2. Materials and Methods

2.1 Study Area

This study was carried out at ILRI (International Livestock Research Institute) Debre Berhan Research Station, in the North Shoa zone of the Amhara Regional State in Ethiopia.

The climatic condition at Debre Berhan area is characterised by biannual rainfall, long dry season and relatively cool temperatures. In Debre Berhan the main rains occur from June to September and short rains occur from March to May but the occurrence of these rains is irregular. The long dry season lasts from October to February with night frosts occurring from November to January.

2.2 Experimental Animals

In this study, two indigenous Ethiopian fat-tailed sheep breeds, the Menz and Horro were used. The breeds are well known and are of great economic importance in the areas of their origin and the production systems they inhabit. They are also easily distinguishable from each other and from other indigenous sheep breeds on the basis of their distinct phenotypic and morphological characteristics.

2.3 Management

2.3.1 Mating

In an effort to obtain contemporary groups of study lambs and to assess the influence of environmental factors, lambs born into the two different seasons (Wet and Dry) were used. Therefore, ewes were mated in Jan/Feb (dry) and in May/June (wet) seasons to ensure lambing into the subsequent wet and dry months, respectively. Breeding ewes were oestrus synchronised prior to mating using progesterone impregnated intrauterine sponges (Intervet International B.V., Boxmeer, Holland) rams selected for mating were also properly checked and underwent breeding soundness tests prior to joining the ewes.

2.3.2 Feeding

All lambs were reared on their dams until weaning at 3 months of age. The feeding of study lambs was in general similar to the conventional feeding practice of the smallholder farmers nearby. Lambs were raised mainly on grazing of natural pasture except for limited supplementation made during the long dry season. During this time, lambs received supplemental hay and were fed in-group on a limited amount of concentrate at a rate of 150g/head/day (composed of 66% wheat bran, 33% Noug cake (oil seed cake) and 1 % salt) in their shade during the evening.

2.3.3 Health and Disease Control

Lambs were routinely checked for any health problems. They were drenched with FASINEX and PANACUR (TAD Pharmazeutisches Werk GmbH, Cuxhaven, Germany) against endoparasites at specific intervals. Newborn lambs were vaccinated against anthrax, clostridial diseases such as blackleg and therapeutic treatments were given to sick animals.

2.4 Experimental layout

Two groups of lambs were used and the grouping was made based on the season of birth of lambs. The first

group included sixty-four lambs (34 Menz and 30 Horro) and the second group included eighty-three lambs (45 Menz and 38 Horro) of both sexes, born into the wet and dry seasons, respectively. The whole study period (12 months) of study lambs was divided into five growth phases (i.e. 1st, 2nd, 3rd, 4th and 5th phases). The division of growth phases was based on the stage of maturity of lambs starting from one to twelfth months of age with an interval of three months between each consecutive growth phases (1, 3, 6, 9, and 12 months). At the end of each growth phase, 5 to 8 randomly selected lambs were slaughtered and dissected to assess the variation in the composition of dissectible body components and the growth and partition of fat among body depots.

2.5 Slaughter and Carcass Dissection

Lambs were slaughtered by severing the jugular vein and the carotid arteries. Blood was collected in a clean bucket and weighed. The weights of skin, head and trotters were also taken. The abdomen was then opened and the gastrointestinal tract (GIT) tied off at the oesophagus and rectum. The GIT was subsequently removed and separated into the various compartments of fore gut, reticulo-rumen and hindgut. The whole of the GIT and its various compartments were weighed full and empty and empty body weight (EBW) was calculated by subtracting digesta weight from the live weight.

During evisceration weights of internal organs (viscera) including empty alimentary tract, heart and pericardium, lungs and trachea, liver, pancreas, kidneys, spleen, urogenital tract, udder (in females), full and empty urinary bladder were taken. In addition, weights of all internal fat depots: kidney fat, urogenital fat, and gut fat (omental and mesenteric – the fatty tissue surrounding the alimentary tract) were recorded. Finally, weights of the hot dressed carcasses were taken and stored overnight at 4°C until dissection the following morning.

Prior to dissection, the weight of each of the cold carcasses was taken, the tail separated from the body and the weight of tail fat recorded. The carcass was then halved longitudinally into two equal right and left halves by sawing down along the dorsal mid line and weights of both the right and left sides were taken. The left side of the carcass was dissected into the components of bone, lean meat, fat (subcutaneous and intermuscular) and sundry trimmings (major blood vessels, ligaments, tendons and thick connective tissue sheets associated with some muscles) and the weights of each were recorded.

2.6 Statistical Analyses

All statistical analyses were made using the Statistical Analysis System (SAS 1990). Weights of lean, bone, fat and sundry trimmings from each of the slaughtered lambs were doubled to give total carcass lean, bone, dissected carcass fat and sundry trimmings of the whole body. Weights of the different fat depots were also summed up to give total carcass fat (TCF). Individual body fat depots were grouped into three major classes: non-carcass fat (NCF – kidney, urogenital and gut fat), carcass fat (CF – subcutaneous and intermuscular fats) and tail fat (TF) to assist the analysis of differential growth and partition of fat among body depots.

Data on empty body, dissectible body components and three classes of body fat depots were analysed using a fixed effects model that included effects of breed, sex, age, possible interactions and body weight (kg) as a covariate using the GLM procedures of SAS (1990). After several preliminary analyses, the following statistical model was selected and fitted to the data:

$$Y_{ijklm} = m + B_i + S_j + A_k + b_{(Xijkl - \bar{X})} + e_{ijklm}$$

Where:

Y = observation on each lamb;

m = Overall mean;

B_i = fixed effect of the ith genotype of the lamb (i = Menz, Horro);

S_j = fixed effect of the jth sex of the lamb (j = male, female);

A_k = fixed effect of the kth growth phase of the lamb (k = 1st, 2nd, 3rd, 4th, 5th growth phases);

$b_{(X - \bar{X})}$ = body weight of lambs (covariable) and

e_{ijklm} = error term.

The significance of the difference among the least squares means of the main effects was tested by Duncan's new multiple-range test. One- and two- factor interactions between main effects were tested and interactions with no significant effects were deleted from the final model.

The allometric growth equation of Huxley (1932) was used to analyse the slaughter and carcass dissection data with the aim of generating information on the growth patterns of the different fat depots and dissectible body components relative to the empty and the whole body. All slaughter and dissection data were first transformed to logarithms (base 10) and log transformed weights of fat depots and dissectible body components were then regressed on total body fat and empty body weight using the allometric equation of the form $Y = aX^b$. This exponential relationship was converted to a logarithmic form to straighten the response curve as follows:

$$\text{Log}_{10}Y = \text{Log}_{10}\, a + b\, \text{Log}_{10}\, X.$$

Where:

Y = is weight of fat depot or weight of dissectible body component;

X= is empty body weight or weight of total body fat;

a = is the value of Y when X = 1 and

b = is the growth coefficient describing proportionate growth of fat in a depot relative to the total body fat/empty body weight or describing the growth of a dissectible body component relative to the empty body weight.

3. Results and Discussion

3.1 Growth and Partition of Fat Depots

The partitioning of fat among major body depots was assessed by expressing the weight of each depot as a percentage of the total body fat. With regard to individual fat depots, results presented in Table 1 show that in the Horro sheep in general, gut fat, tail fat, and subcutaneous fat are the major depots with overall means of 35.7, 33.5, 22.4% and 29.5, 27.5 and 28.7 % in the male and female lambs, respectively. Kidney and urogenital fat, on the other hand, represented the smallest proportion of the total body fat at all the different stages of growth.

With regard to the partition of individual fat depots the trend observed in the Menz sheep (Table 2) were different from that of the Horros. In the Menz sheep, in general, subcutaneous fat, tail fat, and gut fat were the major fat depots with overall means of 32.9, 30.9, 24.9 % and 31.7, 22.6 and 29.8% in the males and females, respectively. As in the Horro's, in the Menz sheep also the kidney and urogenital fat depots

represent the smallest proportion of the total fat with urogenital fat being 4% more in the females than in the males. On the other hand, subcutaneous fat was the major fat depot in the body of the Menz sheep which is contrary to the Horros where gut fat was found to be the major depot.

One common feature observed in both breeds was the pattern of growth of the different fat depots at different stages of growth. In both breeds, the proportion of subcutaneous and tail fat increased progressively with stage of growth and in the later stages of growth, especially during the 4th and 5th growth phase, these depots represented the largest proportion of total body fat.

The grouping of individual depots into the three major classes (i.e. CF, NCF and TF) gave a better analysis of fat growth and patterning with age and growth. In this regard, the least square means analyses presented on Table 3 show the effect of various factors (genotype, sex, growth phase and season of birth) on the three major classes of fat depots. Results obtained indicate that lamb genotype affect carcass ($P<0.001$), non-carcass ($P<0.05$) and tail fat ($P<0.05$). Stage of growth affected ($P<0.0001$) the growth of all three major fat depots with season of birth and sex of lambs having a non-significant effect only on carcass fat.

In Table 4 some differences in the growth and distribution of the CF, NCF and TF were observed at the five different growth phases. In the Horro sheep in general, the overall mean of CF, NCF and TF represented 22.4, 39.9, 33.5% and 28.7, 37.6 and 27.5% of the total dissectible fat in the male and female lambs, respectively. In both sexes, the non-carcass fat represented the largest proportion of the total dissectible fat and the proportion of tail fat is greater in the males than in the females. On the other hand, in the Menz sheep, the CF, NCF and TF represented about 32.9, 29.1, 30.9 % and 31.7, 39.0 and 22.6% of the total dissectible fat in the male and female lambs, respectively (Table 5). Unlike in the Horro's, in the Menz sheep the carcass fat represented the largest proportion of total dissectible fat in both sexes. The proportion and distribution of tail fat was, however, similar in both breeds with the proportion of tail fat being slightly higher in males than in the female lambs.

There is considerable experimental evidence of differences in fat partitioning between and within species (McClelland and Russel 1972). In cattle the existence of breed differences in fat partitioning has long been known and it is widely accepted that extreme dairy breeds deposit a higher proportion of their fat intra-abdominally than do traditional beef breeds (Callow 1948, 1961 and Kempster 1981).

A number of studies have also reported differences in fat partitioning between breeds of sheep. In sheep, Hammond (1932), Zubairov (1966), Ahemedov (1968) and Donald et al. (1970) concluded that breeds differ in their fat distribution. These differences appear to be associated with the maternal traits of the breed, particularly lactation (Thompson and Ball 1997). Farid (1991) working with three fat-tailed Iranian breeds: Karakul, Mehraban, and Baluchi and their crosses with Corriedale and Targhee rams found significant difference between the breeds in body and carcass fat distribution. The small sized Baluchi, which is well adapted to sub-desert conditions, was the fattest and had highest proportions of kidney and tail fat. The Karakul sheep, however, had the highest omental and mesenteric fat, while Mehraban had the thickest subcutaneous fat cover. On the other hand, compared with fat-tailed purebreds, crossbreds were found to contain 18.3% more fat in the body cavity and 64% less fat in the tail region. However, Canton et al. (1992) working with pure and crossbred Black Belly detected no effects of breed but found that hair sheep deposited more non-carcass fat in the internal compartments rather than subcutaneously as wool sheep do. The distribution of fat in the body is also related to the adaptability of animals to particular conditions. For instance, Kempster (1980) indicated that the ability of sheep to survive in hill environments is associated with greater fat deposition in the internal fat depots.

Regarding the distribution of fat as carcass and non-carcass depots, Frutos et al. (1997) working with Churra sheep found that the amount of non-carcass fat as well as its proportion in the empty body is similar to that observed in other milk producing breeds and higher than that of meat breeds. This kind of dichotomy of fat partitioning has been found previously in other sheep breeds (Russel et al. 1971, Butler-Hogg 1984 and Taylor et al. 1989). In general, ewes bred for milk production tend to deposit more fat in internal depots and those bred for meat production deposit more fat in the carcass. Therefore, the result obtained in this study that the Horro sheep deposit significantly ($P<0.05$) more non-carcass fat than the Menz sheep may be related to the good reproductive potential and milking ability of the Horro's as

compared to other indigenous breeds. This is in line with the reports of Galal (1983) who indicated the prolificacy and good mothering ability of the Horro sheep. However, it is in contrast to a litter size of 1.13 and 1.16 reported for Horro and Menz sheep, respectively from the work done at ILRI Debere Berhan Resarch Station (ILRI 1994). On the other hand, the fact that Menz sheep deposit significantly (P<0.001) more carcass fat than the Horro sheep may be indicative of the suitability of this breed for quality mutton production (export market), as fat in the expensive carcass joints, provided it is not in excess, is more valuable than that in the less expensive internal organs.

Reports of sex differences in fat distribution in temperate or tropical sheep breeds are few and there is some degree of uncertainty on how sexes differ in partitioning of fat. However, there is a common view (Butterfield 1988) that the higher fat content in wethers and ewes is basically attributed to higher proportions of subcutaneous fat, which make up for the lower contents of intermuscular fat. But Teixeira et al. (1996), working with Galego Bragancano and crossbred lambs by Suffolk and Merino Precoce sire breeds found that male lambs had lower proportions of internal depots (omental, mesenteric and kidney knob and channel fat) than female lambs. The fact that rams appeared to have higher proportions of fat in the carcass and lower proportions of non-carcass fat depots than wether and ewe lambs reported by Mahgoub and Lodge (1994) is in line with the results of the present study. The fact that female lambs in this study deposited significantly (P<0.05) more non-carcass fat than male lambs agrees with the proposal of Wood et al. (1980). The recent results of Afonso (1992) also support this finding by indicating that milk production and lactational stress results in preferential mobilisation of internal (non-carcass) fat and thus, more fat is deposited internally in the non-carcass depots in the females than in the males. This difference could also be related to the conception of male to female biological difference as suggested by Fourie et al. (1970).

With regard to the effects of stages of growth, results presented in Table 3 show that there is a highly significant difference in the proportion of the different fat depots during the different stages of growth. This is, however, in contrast to the reports of Shemeis et al. (1994). Working on dairy cows Shemeis et al. (1994) found no significant difference among age groups in terms of percentages of total body fat accumulating in the carcass, on the kidneys and around the intestines reflecting a fixed pattern of fat partitioning in response to changes in chronological age. From results of longitudinal studies made on the change in body condition with stages of growth and maturity in Menz and Horro sheep it is clear that the 3rd growth phase is the period where a loss in body condition and reserves occurs in both breeds. The fact that of all the different depots a marked reduction in the proportion of tail fat coincides (Table 4 and 5) with this period may therefore be an indication that selective mobilisation of this depot has occurred in order to fill the gap of prevailing energy deficiency during this growth period.

Table 1. Means and standard errors of individual fat depots as a percent of total dissectible fat in the Horro sheep

Growth phase	Male					Female				
	Renal fat ns	Urog. fat ns	Gut fat *	Tail fat **	Sub. fat ns	Renal fat ns	Urog. fat ns	Gut fat *	Tail fat ns	Sub. fat *
1	8.7 ± 1.1	2.5 ± 0.7	46.6 ± 7.0	24.3 ± 7.0	17.7 ± 6.8	8.3 ± 0.8	5.9 ± 0.9	22.2 ± 4.6	29.3 ± 4.0	34.1 ± 4.3
2	6.6 ± 1.0	1.1 ± 0.6	37.4 ± 6.4	28.3 ± 6.4	26.5 ± 6.2	6.8 ± 0.9	6.2 ± 0.9	37.8 ± 5.1	30.3 ± 4.4	18.8 ± 4.7
3	6.3 ± 1.0	2.2 ± 0.6	51.2 ± 6.5	15.5 ± 6.5	24.6 ± 6.3	8.3 ± 1.0	5.4 ± 1.0	31.4 ± 5.5	21.7 ± 4.8	33.2 ± 5.1
4	4.5 ± 0.9	1.7 ± 0.6	25.7 ± 6.1	46.3 ± 6.1	21.6 ± 5.9	5.6 ± 1.0	9.1 ± 1.0	42.5 ± 5.5	21.6 ± 4.8	21.2 ± 5.1
5	5.6 ± 1.3	2.9 ± 0.8	24.7 ± 8.2	51.4 ± 8.2	15.3 ± 7.9	7.0 ± 0.8	7.2 ± 0.9	24.1 ± 4.6	29.0 ± 4.0	32.5 ± 4.3

* = P<0.05; ** = P<0.001; *** = P<0.0001; ns=not significant

Table 2. Means and standard errors of individual fat depots as a percent of total dissectible fat in the Menz sheep

Growth phase	Male					Female				
	Renal fat	Urog. fat	Gut fat	Tail fat	Sub. fat	Renal fat	Urog. fat	Gut fat	Tail fat	Sub. fat
	ns	***	***	***	**	ns	*	ns	*	ns
1	8.2 ± 1.2	1.8 ± 0.8	24.9 ± 4.1	23.5 ± 4.0	41.4 ± 4.8	9.6 ± 1.0	8.5 ± 1.0	23.4 ± 3.9	24.5 ± 2.2	33.7 ± 4.0
2	9.1 ± 1.1	0.7 ± 0.8	37.2 ± 3.9	16.4 ± 3.7	36.5 ± 4.6	6.0 ± 1.0	5.9 ± 1.0	36.1 ± 3.9	22.8 ± 2.2	29.0 ± 4.0
3	8.1 ± 1.1	4.6 ± 0.7	35.9 ± 3.6	14.6 ± 3.5	36.7 ± 4.2	7.4 ± 1.3	9.4 ± 1.2	30.3 ± 4.9	15.6 ± 2.8	37.2 ± 5.1
4	7.1 ± 1.1	1.6 ± 0.8	21.2 ± 3.8	33.3 ± 3.7	36.6 ± 4.5	8.0 ± 1.1	7.3 ± 1.0	35.4 ± 4.0	19.2 ± 2.3	29.8 ± 4.1
5	6.6 ± 1.0	4.7 ± 0.7	13.8 ± 3.3	54.9 ± 3.2	19.9 ± 3.9	9.7 ± 1.0	5.8 ± 0.9	27.1 ± 3.8	25.6 ± 2.2	31.7 ± 3.9

* = P<0.05; ** = P<0.001; *** = P<0.0001; ns=not significant

Table 3. Least square means and standard errors of the major classes of fat depots as a percent (%) of total dissectible fat

Effects	Carcass fat (Mean ± SE)	Non-carcass fat (Mean ± SE)	Tail fat (Mean ± SE)
Overall ± SD	29.2 ± 13.9	36.1 ± 14.8	28.8 ± 13.7
Breed	**	*	*
Menz	32.6 ± 1.6a	35.6 ± 1.7b	24.8 ± 1.6b
Horro	25.2 ± 1.7b	39.9 ± 1.8a	30.1 ± 1.7a
Sex	ns	*	***
Male	27.6 ± 1.6	35.3 ± 1.7	31.6 ± 1.6a
Female	30.1 ± 1.7	40.2 ± 1.8	23.4 ± 1.7b
Growth phase	***	***	***
1	31.7 ± 2.6	34.7 ± 2.8bc	25.7 ± 2.6bc
2	28.0 ± 2.6	41.6 ± 2.7ba	23.9 ± 2.5c
3	32.8 ± 2.7	44.1 ± 2.9a	15.5 ± 2.7d
4	27.7 ± 2.6	36.6 ± 2.7abc	31.2 ± 2.6b
5	24.1 ± 2.5	31.9 ± 2.7c	40.9 ± 2.5a
Season of birth	ns	**	*
Wet	28.2 ± 1.9	41.4 ± 2.1a	24.8 ± 1.9b
Dry	29.6 ± 1.4	34.1 ± 1.5b	30.1 ± 1.4a

Within variable groups, means with the same letter do not differ significantly (P>0.05).

* = P<0.05; ** = P<0.001; *** = P< 0.0001 ; ns=not significant

Table 4. Means and standard errors of carcass, non-carcass and tail fat depots as percent of total dissectible fat in Horro sheep

Growth phase	Male			Female	
	Carcass fat (%)	Non-carcass fat (%)	Tail fat (%)	Carcass fat (%)	Non-carcass
	ns	*	**	*	*

1	17.7 ± 6.8	49.3 ± 6.8	24.3 ± 7.0	34.0 ± 4.3	28.6 ±
2	26.5 ± 6.2	38.5 ± 6.2	28.3 ± 6.4	18.8 ± 4.7	44.4 ±
3	24.6 ± 6.3	53.1 ± 6.2	15.5 ± 6.5	33.2 ± 5.1	36.8 ±
4	21.6 ± 5.9	31.7 ± 5.9	46.3 ± 6.1	21.2 ± 5.1	52.6 ±
5	15.3 ± 7.9	34.7 ± 7.9	51.4 ± 8.2	32.6 ± 4.3	35.6 ±

* = P<0.05; ** = P<0.001; *** = P< 0.0001 ; ns=not significant

Table 5. Means and standard errors of carcass, non-carcass and tail fat depots as percent of total dissectible fat in Menz sheep

Growth phase	Male			Female	
	Carcass fat	Non-carcass fat (%)	Tail fat	Carcass fat	Non-carcass
	(%)		(%)	(%)	
	**	**	***	ns	ns
1	41.4 ± 4.8	27.9 ± 4.4	23.5 ± 4.0	33.7 ± 4.0	33.5 ±
2	36.5 ± 4.6	38.5 ± 4.1	16.4 ± 3.7	29.0 ± 4.0	44.3 ±
3	36.7 ± 4.2	40.8 ± 3.9	14.6 ± 3.5	37.2 ± 5.1	39.7 ±
4	36.7 ± 4.5	23.1 ± 4.1	33.3 ± 3.7	29.8 ± 4.1	43.5 ±
5	19.9 ± 3.9	21.9 ± 3.5	54.9 ± 3.2	31.7 ± 3.9	36.2 ±

* = P<0.05; ** = P<0.001; *** = P< 0.0001 ; ns=not significant

3.2 Growth of Fat Depots

The allometric growth equation of Huxley (1932) of the form {Y = aXb} in its logarithmic form (base 10) was used to assess differential growth of fat depots in relation to body size during the growth and development of Menz and Horro lambs. Coefficients of the equation relating the growth of the three major classes and individual fat depots relative to total body fat and empty body weight are given in Tables 6 and 7, respectively. With regard to the three major classes of fat depots, the CF, NCF and TF had growth coefficients of 0.99, 0.87 and 1.27 in the Menz and 1.10, 0.79, and 1.22 in the Horro sheep relative to total body fat, respectively. On the other hand, relative to empty body weight, CF, NCF and TF had growth coefficients of 1.10, 1.07 and 1.79 in the Menz and 1.57, 1.35 and 2.11 in the Horro sheep, respectively (Table 6). In both breeds, the result obtained shows that the highest growth coefficient was obtained for TF indicating that it is the late developing depot, while the NCF depot is the early developing one. From results presented in Tables 6 and 7 it is clear that more of the variation in fat depots could be accounted for by variation in total body fat than by empty body weight.

The allometric growth coefficients presented in Table 7 show a similar trend of growth for individual fat depots in both breeds. The result obtained in general shows that relative to total body fat, the kidney, gut and urogenital fats are early growing depots in comparison to the tail and subcutaneous fat depots. Relative to empty body weight, however, the kidney, gut and urogenital fat depots had growth coefficients equal to one or slightly greater than one indicating a proportional growth of the depots with body weight. The tail and subcutaneous fat depots on the other hand, had coefficients of greater than one demonstrating the late maturing characteristics of these depots.

Regarding the growth of fat depots relative to total body fat and empty body weight, results obtained from the *Log/Log* allometric analysis show that the CF and TF appears to be late maturing with a growth coefficient of greater than one. On the other hand, the growth of individual fat depots relative to empty body weight resulted in growth coefficients of 1.04, 0.86, 1.02, 1.23, and 1.76 in the Menz and 1.16, 1.14, 1.38, 1.60 and 1.96 in the Horro for kidney, gut, urogenital, subcutaneous and tail fat, respectively. The result obtained in this regard is slightly different from the results reported by Mahgoub and Lodge (1996).

Working with Omani and Betina goats, Mahgoub and Lodge (1996) reported a slightly higher growth coefficients of 1.51, 1.49, 1.40 and 1.85 for kidney, gut, urogenital and subcutaneous fat relative to empty body weight.

On the other hand, Mtenga et al. (1994) working with male British Saanen goats found that the allometric equations for growth of fat depots (gut fat, channel fat, kidney fat, sub. fat, intermuscular fat) relative to empty body weight were all greater than one indicating that as empty body weight increased the proportions of these depots increased. The largest growth coefficient was for subcutaneous fat, showing it to be the latest developing depot, while kidney and channel fat were the earlier developing ones. This is in agreement with the results of the present study where the largest growth coefficient relative to EBW was for tail and subcutaneous fat while kidney, urogenital and gut fats were relatively early maturing depots with smaller growth coefficients than subcutaneous and tail fats. The results, however, contrast sharply with those reported by Ladipo (1973) using a mixture of male dairy goat breeds slaughtered between 22 and 54 kg live weight. He reported for fat depots the following order of increasing rate: subcutaneous, gut fat (caul and mesenteric), intermuscular fat, and finally visceral fat (kidney, channel and heart fat). The fact that non-carcass fat grew at a higher rate than carcass fat as reported by Mahgoub and Lodge (1994) is contrary to the results of the present work. In general, the result obtained in this study with regard to the order of development of fat depots is in line with the classical view where growth of intra-abdominal (internal body) fat is followed by the growth of subcutaneous and intermuscular fat depots, although there are now some evidences to suggest that intra-abdominal fat has also a later period of rapid growth.

Table 6. Allometric growth equations of the form Log Y = b Log X + a, describing relationship between the three classes of fat depots (Y) and Total body fat and empty body weight (X)

A. Relative to total body fat

Depot (Y)	Menz					Horro				
	a	B	SE (b)	R^2	MSE	a	b	SE (b)	R^2	MSE
CF	-0.5119	0.9975	0.0617	0.770	0.032	-0.8452	1.1005	0.0681	0.816	0.041
NCF	-0.1818	0.8560	0.0653	0.687	0.036	0.0049	0.7946	0.0724	0.671	0.046
TF	-1.2712	1.2709	0.0830	0.750	0.058	-0.1224	1.2197	0.0671	0.720	0.086

B. Relative to empty body weight

Depot (Y)	Menz					Horro				
	a	B	SE (b)	R^2	MSE	a	b	SE (b)	R^2	MSE
CF	-2.1896	1.1041	0.1847	0.314	0.096	-3.9858	1.5795	0.2366	0.430	0.127
NCF	-2.0675	1.0701	0.1623	0.357	0.074	-3.0417	1.3528	0.1769	0.497	0.071
TF	-4.7954	1.7882	0.2047	0.049	0.117	-5.9212	2.1098	0.2474	0.552	0.139

CF= carcass fat; NCF= non-carcass fat; SE = Standard error; MSE = Mean square error; R^2 = Coefficient of determination; TF = Tail fat

Table 7. Allometric growth equations of the form Log Y = b Log X + a, describing relationship between individual fat depots (Y) and Total body fat and empty body weight (X)

A. Relative to total body fat

Depot (Y)	Menz					Horro				
	a	b	SE (b)	R^2	MSE	a	b	SE (b)	R^2	MSE
Renal fat	-0.0879	0.9004	0.0626	0.752	0.028	-0.4194	0.6764	0.0694	0.659	0.036
Gut fat	0.0271	0.7253	0.0809	0.541	0.047	0.2464	0.6459	0.1005	0.457	0.076
Subcutaneous fat	-0.5302	0.9995	0.0654	0.774	0.031	-0.9296	1.1340	0.0741	0.826	0.041
Urogenital fat	-0.8132	0.7936	0.1004	0.478	0.073	-1.1242	0.8962	0.1083	0.582	0.089
Tail fat	-1.3009	1.2839	0.0894	0.752	0.058	-1.0144	1.1710	0.1079	0.706	0.088

B. Relative to empty body weight

Depot (Y)	Menz					Horro				
	a	b	SE (b)	R^2	MSE	a	b	SE (b)	R^2	MSE
Renal fat	-2.5546	1.0417	0.1682	0.360	0.074	-3.0328	1.1607	0.1653	0.501	0.053

Gut fat	-1.3986	0.8642	0.1700	0.275	0.075	-2.3891	1.1464	0.2128	0.372	0.088
Subcutaneous fat	-1.8866	1.0236	0.1938	0.291	0.098	-4.0492	1.6024	0.2654	0.426	0.138
Urogenital fat	-2.6514	1.0221	0.1966	0.284	0.101	-4.0105	1.3810	0.2645	0.357	0.137
Tail fat	-4.6887	1.7671	0.2099	0.510	0.115	-5.3786	1.9657	0.2730	0.5141	0.146

SE = Standarad error; MSE = Mean square error; R^2 = Coefficient of determination

In general, clear differences in the growth and partition of fat among body depots of Menz and Horro sheep breeds and the different sexes were observed. The Menz sheep showed the tendency to deposit more fat into the carcass depot as compared to the NCF depots in the Horro sheep. The fact that females deposit more non-carcass fat as compared to male lambs at any one stage of growth may be related to the fact that milk production and lactational stress results in preferential mobilisation of NCF depots and thus more fat is deposited internally in the females than in the males.

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