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BARBER, SARAH ANN

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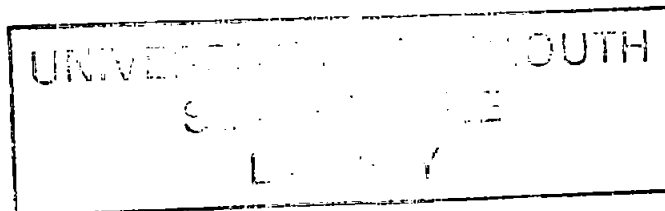
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SARAH ANN BARBER

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Abstract

Growth, carcass composition and meat quality of Angora goats reared for fibre production

Sarah Ann Barber

The effects of age and plane of nutrition on the body and carcass composition and mohair fibre yield and quality of British Angora wether goats slaughtered at six, 12, 18 and 24 months of age were investigated. Carcass yield, composition and conformation improved with increasing age and plane of nutrition. Greasy fleece weight also increased with increasing age and plane of nutrition but fibre quality declined since the increase in mass was achieved by means of increased fibre diameter with no effect of age or plane of nutrition on the fibre elongation rate. There was a constant relationship between the increase in fibre diameter with age and fleece mass which was not affected by plane of nutrition. Similarly there was no significant effect of plane of nutrition on the relationships between fibre diameter and the weight of various body and carcass components. A strong relationship between fibre diameter and the weight of fat in the body or carcass suggested that the increase in fibre diameter with age of the goat was influenced by cumulative feed intake rather than by fat-free body size.

The allometric growth patterns of the body and carcass of the Angora goat conformed with the patterns established for other domestic species, with early maturity of the external offal and vital organs, later maturity of the carcass and body fat, and a centripetal pattern of development. There was no effect of plane of nutrition on the allometric growth patterns of the fat-free body or carcass, but decreasing the plane of nutrition resulted in a uniform retardation of all body parts and carcass tissues and a significant effect on the relative growth rate of body and carcass fat.

Regression equations were formulated to predict the half carcass composition of Angora wether goats using sample joint dissection data. The most accurate predictions were achieved with data from the leg and the best end of neck combined in multiple regression equations.

A second experiment to investigate the effects of long term undernutrition followed by realimentation on the growth rate and composition of empty body weight gain revealed no evidence of compensatory liveweight gain in the Angora goat.

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List of abbreviations

r	correlation coefficient
R^2	regression coefficient
b	allometric coefficient
DM	dry matter
g	gramme
kg	kilogramme
$kg^{0.75}$	metabolic body size
ME	metabolizable energy
MJ	megajoule
>	greater than
<	less than
mm	millimetres
m	metres
NS	not significant
P	probability level
*	$P < 0.05$
**	$P < 0.01$
***	$P < 0.001$
s.e.	standard error
s.d.	standard deviation
H	high
M	medium
L	low
KKCF	kidney knob and channel fat
IMF	intermuscular fat
SCF	subcutaneous fat
n	number of replicates per mean value
μm	micrometre / micron (10^{-10}m)
EBW	empty body weight
WCW	warm carcass weight
CCW	cold carcass weight
DLWG	daily liveweight gain
M	male
F	female
C	castrate

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Author's declaration

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award.

Relevant scientific seminars and conferences were attended at which work was presented; external institutions were visited for consultation purposes and several papers prepared for publication.

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External contacts: British Angora Goat Society; Meat Research Institute, Bristol.

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Date........22 /2 /95....................

1 Introduction

Although currently the largest single importer and processor of mohair fibre produced worldwide, the United Kingdom has remained a minor producer since the introduction of the first Angora goats to the country in 1981. By 1991 the number of U.K. registered breeding does had increased to approximately 2000, with fibre quality equivalent to that provided by the South African, Texan and Australasian producers, but British farmers were struggling to compete due to the relatively low quantity of mohair produced in the U.K. per annum (Veysey, personal communication).

In a report commissioned jointly by the British Angora Goat Society and Food From Britain, Thelwall (1988) confirmed the feasibility of U.K. mohair production but highlighted the preeminently fashion dependent nature of the industry which results in considerable fluctuation in mohair price. He emphasised the importance of meat production to the long-term success of the industry and stressed that a stable income from meat would be essential in order to maintain profitability and encourage further U.K. mohair production.

However, there has been very little investigation into the production and quality of goat meat, particularly under temperate conditions. Few existing reports relate specifically to the Angora, so there is limited information on which to base management advice, particularly with regard to nutrition. It is also possible that any techniques adopted for the improvement of carcass quality and yield may be detrimental to the primary objective of producing high quality mohair fibre, since nothing is known of the relationship between the development of the carcass and fibre quality.

Therefore the aim of this study was to examine the growth and carcass development of the Angora goat with age and at different levels of nutrition and to relate this development with the concomitant changes in fibre yield and quality under U.K. conditions. The study concentrated on the male castrate (wether) since this constitutes the major source of meat. Furthermore, castration tends to increase carcass fatness. This could be desirable in the case of the goat whose carcass is often considered 'over lean' by the butcher.

2 Review of the literature

2.1 Growth and development of body and carcass components in domestic livestock

The growth of an animal is generally described in terms of an increase in body weight with time, and of the changes in the form of the animal with increasing maturity. The relationship between body weight and time is sigmoid for most species, with a "self-accelerating" phase, a point of inflection which generally coincides with puberty, and a "self-decelerating" phase (Brody, 1964). Within the pattern of growth of the whole body there is a regular and systematic pattern of growth of the body organs, tissues and parts, the growth of each component following a temporal pattern similar to that of liveweight. Changes in the form of the animal result from differences in the relative growth rates of the component body parts which lead to differences in their proportions as the animal grows.

These sequential growth patterns were first described in the sheep by Hammond (1932) who referred to parts as 'early'- or 'late'-maturing according to the sequence in which they reached their maximum absolute growth rate. In this and later studies by the Cambridge school of workers, summarised by Pálsson (1955), patterns of development of domestic livestock were established. The order in which the body organs attain their maximum growth rate was thus; eyes, kidneys, heart, thoracic organs, digestive tract. The order of development of the carcass tissues was; nervous tissue, bone, muscle and fat, with fat developing in the various depots at different rates in the following order of increasing rate; mesenteric fat, kidney fat, intermuscular fat and subcutaneous fat.

These same studies also identified a directional pattern of growth of the body comprising a primary wave of increasing growth intensity from the cranium down to the facial parts of the head and backwards to the lumbar region with a secondary wave of growth from the lower limbs down to the digits and upwards along the limbs to the trunk and lumbar region. A similar pattern of centripetal development was also observed within each of the major tissues of the carcass.

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The growth intensity of the whole body (or the relative growth rates of its parts) is therefore distributed according to a fixed and orderly system of growth gradients which were first described mathematically by Huxley (1932). Over a given period of growth there is a constant ratio between the growth rate of a body component (y) and that of the whole body (x) which conforms to the model:

$$y = ax^b$$

where b is the "allometric growth coefficient". The application of Huxley's allometric equation enables the maturity of a part, tissue or organ in relation to another determining part of the animal or the whole animal, to be expressed mathematically. When b = 1 the growth rates are the same and the two parts remain in the same proportion over a given weight range; when b > 1 the proportion of y to x increases as the weight of x increases and y is considered relatively late-maturing; when b < 1 the proportion of y to x decreases as the weight of x increases and y is considered relatively early-maturing.

Allometric growth coefficients give an indication of the rate of maturity of one part compared with another and have been used to describe the order of maturity of body and carcass components in most domestic species including pigs (Davies, 1974), sheep (Fourie, Kirton and Jury, 1970; Murray and Slezacek, 1976), cattle (Berg and Butterfield, 1968; Mukhoty and Berg, 1971) and goats (Fehr et al., 1976; Owen et al., 1978; Colomer-Rocher and Kirton, 1989). A detailed knowledge of differential growth rates is essential in order that appropriate nutrients may be supplied at the relevant stage of development in order to benefit the growth of a particular body or carcass component. This has assisted in the factorial estimation of the nutrient requirements of growing pigs (Moughan, 1989), sheep and cattle (Agricultural Research Council, 1980).

At present there is insufficient knowledge of the differential growth rates of goats to allow detailed estimation of their nutrient requirements. However, there is little variation between species in the overall pattern of maturity since it is based on the functional importance of the parts or tissues for survival of the individual (Pálsson, 1963). Thus carcass dissection studies

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on various breeds of goat have confirmed that skeletal tissue matures earlier than muscle and that fat is the latest developing tissue (Table 2.1). Consistent with this, among the chemical body components water is early maturing, lipid is a late developing tissue and the growth of protein is generally isometric with total body growth (Table 2.1).

The carcass cuts, having varying proportions of bone, muscle and fat, also exhibit differential growth with respect to the whole carcass. The loin is generally the latest developing cut followed by the breast and best end of neck, with the shoulder and then the leg the earliest developing joints (Table 2.1), an order of development which clearly follows the centripetal growth pattern described by the Cambridge school. Wilson (1958b), Owen *et al.* (1977) and Owen and Norman (1977) also established a centripetal growth pattern in East African Dwarf goats and Botswana goats respectively by means of the relative changes in body and carcass linear measurements and joint proportions with age.

The vital organs and alimentary canal are all relatively early developing, as are the external offal (head, skin and feet) and thus have a low growth impetus post-natally (Wilson, 1958b; Gaili, 1976; Owen and Norman, 1977). Morand-Fehr (1981) gives the order of maturity of the offal parts, from the earliest to the latest, as: head, skin, red offal (kidneys, heart, liver, lungs), gastro-intestinal organs (abomasum, intestine, omasum, rumen-reticulum). The majority of post-natal whole body growth is therefore due to that of the carcass. Estimates of the allometric coefficient for the carcass vary between 1.0 and 1.33, being influenced by the rate of fat deposition in the carcass (McGregor, 1982; Warmington and Kirton, 1990).

The differential development of total body fat in the goat has been poorly documented. Colomer-Rocher and Kirton (1989) studied the allometric development of carcass fat in New Zealand Saanen goats. In female goats the order of increasing fat maturity was intermuscular, pelvic, subcutaneous, kidney fat, with allometric coefficients ranging from 1.79 for intermuscular fat to 2.65 for kidney fat, indicating the late maturing nature of fat relative to the fat-free carcass. Similarly McGregor (1982) reported an order of fat development of Saanen wether goats as carcass fat, caul fat, channel fat with allometric coefficients ranging from 2.155 for carcass fat to 2.665 for channel fat. The later maturity of KKCF compared

with carcass dissectible fat in these two studies was the opposite situation to that reported for other domestic species by Pálsson (1955). This was attributable to the greater fatness of the female and castrate goats compared with the animals used in the Cambridge experiments, since the order of maturity of the fat depots in leaner male Saanen goats (Colomer-Rocher and Kirton, 1989) confirmed that reported by Pálsson.

Allometric coefficient			Sex	Weight range (kg)	Source
Dissectible components					
Bone	Lean	Fat			
0.741	1.067	1.823	M	Birth 33	Morand-Fehr (1981)[a]
0.776	1.170	1.995	C	20 - 46	Owen et al. (1978)[b]
0.87	0.99	1.25	M	2 - 52	Colomer-Rocher &
0.49	0.83	2.05	F	8 - 32	Kirton (1989)[a]

Chemical components					
Water	Protein	Lipid			
0.91	1.04	1.43	M	2 - 52	Colomer-Rocher &
0.73	0.76	1.92	F	8 - 32	Kirton (1989)[a]
	0.930	2.155	C	17 - 74	McGregor (1982)[c]

Commercial joints							
Leg	Shoulder	Best end	Breast	Loin			
0.988	0.921	1.034	1.175	1.155	M	birth - 33	Morand-Fehr (1981)[a]
0.948	1.017	0.951	1.034	1.107	M	7.6 - 32.3	Gaili (1976)[a]
0.88		1.29			F & C	14 - 46	Butler-Hogg &
							Mowlem (1985)[a]

[a] relative to carcass weight;
[b] relative to EBW;
[c] relative to fasted liveweight

Table 2.1

Allometric growth coefficients of dissectible and chemical components and commercial joints of goat carcasses (adapted from Warmington and Kirton, 1990)

2.2 Factors affecting differential growth rates

2.2.1 Plane of nutrition

Huxley's allometric equation (1932) implies that the size of a part is virtually determined by the total weight of the animal. This idea was rejected by the Hammond school who demonstrated large differences in the body proportions of pigs (McMeekan, 1940a, b, c) and sheep (Pálsson and Vergés, 1952) reared to the same body weights along different growth curves. They subsequently advanced the hypothesis that under-nutrition penalized the growth of body components differentially in the reverse order of their maturity, late maturing tissues and parts being the most affected, and that those body components having their maximum growth intensity at the time of restriction were the most retarded (Pálsson, 1955). However Wallace (1948) observed that the proportions of parts and tissues in animals slaughtered in these experiments appeared normal in relation to the total weight of the tissue. Wilson (1954a) in his study of the domestic fowl, showed that the main effect of nutritional treatments was upon the fat tissues, which resulted in large differences in the proportions of other tissues when compared at equal body weights. In a later study of the East African Dwarf goat, Wilson (1960) confirmed that there was no effect of plane of nutrition on the body proportions of goats slaughtered at equal fat-free empty body weights. Tulloh (1963) and Elsley *et al.* (1964), using the original Cambridge data, subsequently demonstrated that the allometric relationship between body parts, when considered on a dissectible fat-free basis, was not disturbed by nutritional treatment, and concluded that when feeding is restricted there is a uniform retardation of the lean tissues accompanied by variation in the fat content of the body. Therefore within a species, muscle and bone bear a definite relation to body size, but nutritional extremes that produce variable fat deposition can alter this relationship.

2.2.2 Breed

Significant differences between breeds within a species in the differential growth rates of the carcass tissues relative to fat-free carcass (muscle plus bone) weight have been identified.

Davies (1974) and Fourie *et al.* (1970) found significantly different allometric coefficients for bone, but not muscle, between breeds of pigs and sheep respectively, resulting in differences in lean:bone ratios at equal lean plus bone weights. Similarly Mukhoty and Berg (1971), in a comparison of several breeds of cattle, found significant breed differences in muscle and bone weight when adjusted to a common muscle plus bone weight, although breeds were found to have similar growth coefficients for the two tissues. These effects were primarily due to differences in the degree of maturity at the same body weight, smaller animals being earlier maturing than larger animals (Agricultural Research Council, 1980). Much of the body compositional variation which exists between breeds of sheep and cattle, and also between species, disappears when comparisons are made at the same proportion of mature size (Taylor, 1980; Thonney *et al.*, 1987b, c; Butterfield, 1988; Gaili, 1993). No such comparative studies have yet been made between goat breeds, but the large range of mature body weights among breeds of goat (Table 2.2) suggests that most of the variation in the body and carcass proportions of goats reported in the literature is attributable to differences in maturity.

Breed, country	Mature weight (kg)
Boer, S. Africa	100 - 110
Saanen, Britain / Australia	90 - 100
Damascus, Cyprus	80 - 90
Alpine, France	80 - 90
Anglo-Nubian, Worldwide	80 - 90
Angora, Texas / Australia	50 - 60
Angora x Australian feral	45 - 55
E. African Dwarf	20 - 25

Table 2.2

Mature size of some common breeds of goat

(from McGregor, 1985a)

Significant breed effects on the relative growth rate of fat with respect to fat-free carcass weight have been reported in sheep (Fourie *et al.*, 1970) and cattle (Mukhoty and Berg, 1971), suggesting either a genetic influence on the rate of fat deposition, on the time of onset

of the fattening phase or on the partitioning of total body fat between the various body and carcass depots. Kempster (1980-81) concluded that extreme dairy breeds of cattle deposit a higher proportion of their total fat internally (as KKCF) and a lower proportion subcutaneously than traditional British beef breeds, and Pálsson (1940) reported that mountain breeds of sheep tend to accumulate more internal body fat than more specialised meat breeds. Shafrir and Wertheimer (1965) found that the internal fat depots are metabolically more active while subcutaneous fat is a less active depot. There have been no direct comparisons of fat partitioning between goat breeds at equal total fatness but the diversity of goat breeds and their end products suggests that some of the variation in the weights of body and carcass fat depots reported in the literature might be due to differences in fat partitioning between extreme types.

2.2.3 Sex

Sex effects on carcass differential growth rates have been recorded in sheep (Fourie *et al.*, 1970), cattle (Mukhoty and Berg, 1971), pigs (Davies *et al.*, 1980) and goats (Wilson, 1960; Colomer-Rocher and Kirton, 1989), females generally having lower coefficients for bone and muscle and higher coefficients for fat. These effects are again mainly attributable to differences in the mature size of male, female and castrate animals. Mukhoty and Berg (1971) found growth coefficients for fat to be 1.10, 1.18 and 2.15 for bulls, steers and heifers respectively, but since these values were not significantly different, attributed the observed differences in the weight of fat at a common muscle plus bone weight to the earlier onset of fattening in the heifers rather than to differences in the relative rate of fattening.

2.2.4 Species

Using the principals of differential growth, Owen *et al.* (1978) suggested that the goat is a relatively later maturing species than the sheep. When compared at the same age, native Botswana goats had a higher allometric growth coefficient for carcass lean tissue but a lower coefficient for carcass dissectible fat relative to empty body weight than Botswana sheep. Furthermore the early maturing leg and shoulder joints decreased as a proportion of the

carcass with increasing age more rapidly in the goats than in the sheep (Owen and Norman, 1977). These effects may have been due to differences in the relative rate of fattening of the two species, an earlier onset of fattening in the sheep or to slower growth rates in the goats resulting in greater maturity of the sheep at comparable ages.

There have been few other direct comparisons of differential growth rates between species. However, Davies (1974), using allometric equations formulated by Tulloh (1963) from the Cambridge data, demonstrated a similarity in muscle:bone ratios of both new-born and mature sheep, pigs and cattle which suggested that between species there is little difference in the relative growth of muscle and bone provided they are compared at equal maturity. Similarly Taylor (1980) showed that much of the variation among animals of different species was reduced after applying genetic size-scaling, i.e. taking into account differences in mature size. However, Thonney et al. (1987b) found that even when compared at equal proportions of mature weight British feral goats had a greater proportion of total muscle than several breeds of sheep.

2.3 Effects of differential growth patterns on body and carcass composition

The goat has frequently been compared with the sheep in terms of its growth performance and body and carcass composition, presumably due to their similarities in size and physiology compared with other domestic species. However, goats are rarely reared under similar conditions of nutrition and management as sheep, not least because so little is known of the specific nutrient requirements of the growing kid, the lactating doe or the fibre producing goat. Furthermore, the differences that exist between breeds of goat are often as great as those between goats and sheep, particularly when the diversity of end products obtained from goats is taken into consideration. It is therefore not entirely valid to make such species comparisons, but as a highly developed meat producing species with a carcass not dissimilar to that of the goat, the sheep is a useful species with which to compare the goat in order to assess the current status of the latter as a meat producing animal.

2.3.1 Killing-out percentage

The economic value of a meat animal is dependent upon its killing-out percentage. The interpretation of published data for the goat is complicated by the variation in gut contents which results from different pre-slaughter fasting regimes, or the use of empty body weight or liveweight, and by differences in the definition of the carcass (Kirton, 1988). Based on empty body weight, values range from 65% in kids to as low as 40% in cull animals (Gall, 1982). Consistent with an allometric coefficient for the carcass of greater than 1.0, killing-out percentage increases with the age and weight of the animal. As with other domestic species the value also increases with fat deposition in the carcass and varies depending on the sex and breed of the animal (Table 2.3). Carcass weights therefore vary between 10kg in the smaller African breeds to 50kg in the larger Saanen and the South African Boer goat (Kirton, 1988). Since the majority of goat breeds have a smaller mature size than these two extremes goat carcasses tend to be smaller than similar aged sheep.

Several studies have suggested that carcass yield differs between breeds of goat (Owen and Norman, 1977; Smith *et al.*, 1982) but have not compared breeds reared under identical

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systems of nutrition and management or slaughtered at the same degree of maturity. From the observations in Table 2.3 it appears that the killing-out percentages of different goat breeds are similar, averaging 50%, when differences in fatness, maturity and mature body size are considered. A possible exception is the South African Boer, one of the largest goat breeds and the only specialised meat breed, which had a greater dressing percentage than the smaller native Botswana goat when compared at the same age (Owen and Norman, 1977) and a similar or greater dressing percentage than three South African sheep breeds when compared at the same liveweight (Naudé and Venter, 1977).

Studies of the killing-out percentages of goats and sheep have yielded variable conclusions because the comparisons were not made at equal stages of carcass maturity and often gave no indication of the mature size of the breeds involved. Thus Owen and Norman (1977) and Miller *et al.* (1943) found the killing-out percentages of Botswana and Angora goats to be similar to those of sheep of comparable ages and empty body weights respectively (Table 2.3). However, Smith *et al.* (1982) found that at similar ages Angora and Spanish goats had significantly lower dressing percentages with higher percentages of head, feet, pelt and internal organs than sheep, suggesting that the goats were less mature than the sheep. At an equally adjusted empty body weight, Sudan desert sheep which had been fattened on a concentrate ration had heavier carcasses than goats fattened on the same diet, since the goats tended to deposit body fat around the gastro-intestinal tract rather than in the carcass (Gaili and Ali, 1985a). For this reason Fehr *et al.* (1976) observed a tendency for the dressing percentage of Alpine kids to *decrease* with increasing liveweight, over the range of liveweights studied, because of the increasing volume of the visceral mass (Table 2.3). Therefore at equal maturity goats would be expected to have poorer killing-out percentages than sheep due to the differences in fat partitioning between the species, goats tending to deposit a greater proportion of total fat internally rather than in the carcass. This was substantiated by Thonney *et al.* (1987b) who compared British feral goats with several breeds of sheep at equal proportions of their mature empty body weight and found the goats to have a lower carcass yield but higher proportions of omental plus mesenteric and perirenal fat than was expected for their stage of maturity.

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Source	Breed/species	Sex	Age	EBW (kg)	KO%
1.	Angora goat	C	1 year	27.3†	50.5
			2 years	29.5	54.1
			3/4 years	38.6	54.5
	Rambouillet lamb	C		30.0	50.0
2.	Angora goat	C	16 months	29.7	54.0
3.	New Zealand feral	M	Young - aged	7.3 - 36.1‡	44.6
	goat	F		3.6 - 26.1	42.2
4.	Alpine goat	M	8 weeks	16.2	52.8
			11 weeks	22.2	53.7
			18 weeks	27.4	51.1
			24 weeks	32.6	52.0
5.	S. African Boer goat	C	8 - 35 weeks	10.0 - 40.0	48.3
	S. African mutton-merino sheep	C		10.0 - 40.0	46.6
	Merino sheep				41.0
	Dorper sheep				48.5
6.	Botswana goat	M	1 year	16.0	48.7
		C	1 year	20.1	52.0
			3.5 years	34.5	53.0
			4.5 - 5 years	45.8	55.8
		F	4.5 - 5 years	32.8	47.0
	Boer goat	M	1 year	26.6	56.2
	Botswana sheep	C	1 year	22.6	52.0
			3.5 years	31.0	53.7
		F	4.5 - 5 years	27.2	52.5
7.	Sudan desert goat	M	Yearling	12.5‡	40.4
			Yearling	25.0	49.0
8.	Sudan desert goat	M	Yearling	18.0	47.6
	Sudan desert sheep		Yearling	18.0	51.5

1. Miller *et al.* (1943) 2. Shahjalal *et al.* (1991) 3. Kirton (1970) 4. Fehr *et al.* (1976) 5. Naudé & Venter (1977) 6. Owen & Norman (1977) 7. Gaili *et al.* (1972) 8. Gaili & Ali (1985a);
†24-hour shrunk weight;
‡liveweight.

Table 2.3

Killing-out percentages of goats and sheep

2.3.2 Carcass composition

A knowledge of the quantity and distribution of fat, lean, and bone throughout the carcass is important in order to assess the animal as a meat producer, since it is this that determines the quality of the carcass produced. As with other domestic species there is an increase in the proportion of carcass fat and a reduction in the proportions of lean and bone with increasing age and carcass weight of the goat (Table 2.4), which is consistent with the allometric coefficients for these carcass tissues (Table 2.1). The more rapid decrease in bone proportion compared with that of lean results in an increase in the lean:bone ratio with increasing carcass weight.

Average values for the tissue contents of goat carcasses vary between 55 and 70% for muscle and between 12 and 26% for bone (Table 2.4), the values being dependent on the age and slaughter weight of the animal (Naudé and Venter, 1977; Owen *et al.*, 1978; Colomer-Rocher and Kirton, 1989). Level of nutrition (Wilson, 1960), breed (McGregor, 1982; Treacher *et al.*, 1989) and sex (Colomer-Rocher and Kirton, 1989) may also affect the proportions of lean and bone but these effects are mainly attributable to variation in the degree of maturity of the carcass and its fatness. When comparisons are made on a fat-free basis, there is little variation that cannot be accounted for by differences in carcass weight (Wilson, 1960; Gall, 1982). Consequently lean:bone ratios vary little between breeds, generally ranging between 2.0 and 3.0 depending on the weight of the carcass. Again the South African Boer goat is a possible exception, appearing to be a more muscular type with lean:bone ratios exceeding 5.0 in the most mature carcasses (Naudé and Venter, 1977).

The most variable tissue in the carcasses of goats is fat since this can be affected by many factors including breed, age, liveweight, sex and nutrition (Owen *et al.*, 1978). The carcasses of goats generally contain a lower proportion of fat than the carcasses of sheep reared under the same conditions (Table 2.4). Values for goats are commonly between 10 and 20% but can range from 4% in young, unfattened goats to over 30% in mature female goats, while lamb carcasses generally contain 20 to 35% dissectible fat (Gall, 1982; Kirton, 1988). Comparisons of carcass fat content are complicated since KKCF may or may not be included

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Source	Breed/species	Sex	Carcass wt. (kg)	Carcass composition (%)			Lean : Bone
				Fat	Lean	Bone	
1.	Boer goat	C	4.0	9.4	70.0	20.6	3.4
			12.0	18.2	68.0	13.8	4.9
			17.0	23.4	64.0	12.6	5.1
			22.0	24.5	63.5	12.0	5.3
2.	Saanen goat	M	5.0	9.9	60.9	25.6	2.4
			20.0	14.0	60.1	21.5	2.8
			50.0	17.6	59.7	19.2	3.1
		F	10.0	10.6	61.8	24.7	2.5
			20.0	22.0	55.1	17.4	3.2
			30.0	33.7	51.5	14.1	3.7
3.	Angora goat	M	12.3	14.1	63.4	22.5†	2.8
	Spanish goat		16.6	13.5	64.4	22.1	2.9
	Rambouillet, Barbado & Karakul sheep		20.5	18.7	59.8	21.5	2.8
	Angora goat	F	12.5	11.7	63.4	24.9†	2.5
	Spanish goat		16.3	19.5	57.7	22.8	2.5
	Rambouillet, Barbado & Karakul sheep		20.3	21.2	57.2	21.6	2.6
4.	Saanen, Toggenberg, Alpine & Nubian goats	M	13.5	19.5	58.2	22.3	2.6
			22.2	23.5	57.4	19.0	3.0
	Blackface sheep		24.0	29.4	53.5	17.1	3.1
5.	Boer goat	M	13.4	9.3	62.4	19.9	3.2
	Botswana goat		7.3	6.7	59.8	25.3	2.4
	Botswana goat	C	9.9	10.8	58.9	23.1	2.6
	Botswana sheep		11.1	21.2	52.6	20.5	2.6
	Botswana goat	C	17.6	14.8	59.1	20.2	3.0
	Botswana sheep		15.9	27.6	49.4	17.9	2.9
	Botswana goat	F	14.8	13.3	58.8	20.8	2.9
	Botswana sheep		14.7	23.3	52.2	18.7	2.9
6.	Sudan desert goat	M	8.16	4.3	55.1	26.1	2.1
	Sudan desert sheep		8.16	8.9	54.6	24.6	2.2

1. Naudé and Venter (1977) 2. Colomer-Rocher and Kirton (1989) 3. Smith *et al.* (1972)
4. Ladipo (1973) 5. Owen *et al.* (1978) 6. Gaili & Ali (1985a);
† Composition of wholesale rack (6th to 12th rib)

Table 2.4

Comparison of the carcass composition of goats and sheep

and this is not always stated. The low fat content of goat carcasses results in greater proportions of lean and bone compared with lamb carcasses, but lean:bone ratios are generally similar for the two species (Table 2.4) any differences being mainly attributable to differences in the mature size of the two species or in the maturity of the animals in question.

The lower fat content of goat carcasses compared with those of sheep may be due to a later onset of fattening or to a slower rate of fattening in the goat, but is most probably attributable to a difference in the partitioning of total body fat into carcass and non-carcass fat depots. Goats deposit a greater proportion of total fat in the non-carcass depots than sheep and a smaller proportion as subcutaneous carcass fat (Table 2.5). Thus Thonney *et al.* (1987b) found that British feral goats had a greater percentage of omental plus mesenteric fat and perirenal fat than several breeds of sheep when compared at equal maturity. Attempts to increase carcass fatness have therefore led to an increase in non-carcass fat, since much of the fat that was deposited tended to be directed into the kidney and pelvic regions (Naudé and Venter, 1977; Smith *et al.*, 1978) and the gastro-intestinal tract (Gaili and Ali, 1985a).

	Goats	Lambs
SCF	14.1	29.7
IMF	39.8	45.0
KKCF and heart fat	15.4	10.6
Visceral fat	29.6	15.3

Table 2.5
Locations of separable fat in goats and lambs expressed
as percentage of total separable fat (Ladipo, 1973)

Conversely goat carcasses have an exceptionally low proportion of subcutaneous fat which rarely exceeds 2mm in thickness and is often absent altogether (Kirton, 1970; McGregor, 1980; Hogg *et al.*, 1989). In a comparison of the carcass characteristics of the Boer goat with several South African sheep breeds, subcutaneous fat depth averaged 2.3mm for the goat carcasses and between 5.4 and 5.9mm for the sheep carcasses (Naudé and Venter, 1977). As a consequence of their thin subcutaneous fat cover goat carcasses require minimal fat trim, and hence their saleable meat yield approaches 100% of carcass weight in goats slaughtered

over a wide range of liveweights (Gaili *et al.*, 1972; Butler-Hogg and Mowlem, 1985). However, poor subcutaneous fat cover can have an adverse influence on the storage and eating quality of the meat (Owen, 1975; Fehr *et al.*, 1976). Toughness has been attributed to cold-shortening of the muscle fibres following rapid chilling of the warm carcass (Smith *et al.*, 1976). The poor subcutaneous fat cover of goat carcasses predisposes them to this phenomenon and consequently Smith *et al.* (1978) assigned higher toughness scores to kid meat than to that of older, fatter goats. Almost without exception, when compared with meat from other domestic species, sensory panel discrimination against goat meat has been due to a lack of tenderness with no indication of any strong flavour or odour (Miller *et al.*, 1943; Kirton, 1970; Gaili *et al.*, 1972; Smith *et al.*, 1974).

The intramuscular fat content of goat meat is low at around 2% of fresh matter (Gonzalez *et al.*, 1983; Hogg *et al.*, 1989) and is significantly lower than that of sheep of equal liveweight. Babiker *et al.* (1990) recorded a value of 2.8% of fresh matter for the Sudan desert goat compared with 3.5% in lambs while Gaili and Ali (1985b) found values of 9.2% and 20.4% on a dry matter basis in goats and sheep respectively. The greater intramuscular fat content of the sheep carcasses may have been due to their greater total fat content (Gaili and Ali, 1985a) since *ad libitum* feeding of a concentrate diet increased the intramuscular fat of the goat carcasses to 18.5%.

The few complete studies of total fat distribution in the goat suggest that about 25% of the body fat is situated within and between the muscles and that about 50 to 60% is in the body cavities (Wilson, 1958b; Ladipo, 1973; Gall, 1982).

There have been few comparisons of different goat breeds reared under identical systems of nutrition and management, but indirect comparisons suggest that breed differences exist in carcass fat deposition. Dairy goats appear leaner at any liveweight than Angora goats (McGregor, 1982; Morand-Fehr *et al.*, 1986). This may be a reflection of their greater mature size and later maturity rather than a breed difference in fat partitioning (McGregor, 1980) but breed differences in fat partition in sheep and cattle are known to exist (Ledger, 1959; Kempster, 1980-81). The Angora goat and its crosses with dairy goats appear to have a

carcass more similar in composition to that of the lamb, with a lower proportion of bone, a higher proportion of carcass fat and higher lean to bone ratios than pure bred dairy goats (Table 2.6). Again these differences are probably attributable to the smaller mature size of the Angora which results in a more mature carcass at equal slaughter weights (McGregor, 1980). However the Angora has a more favourable fat distribution, with greater subcutaneous fat cover, more intermuscular fat and less kidney fat than other breeds (Fehr *et al.*, 1976; Mowlem, 1988).

	Component (% of carcass weight)†				Kidney fat*
	Muscle	Bone	SCF	IMF	
Lamb (unspecified breed)	55.0	12.0	16.0	17.0	4.1
Dairy kid	55.9	15.4	6.7	14.3	8.1
Angora x British Saanen kid	56	14.6	12.5	17.0	4.6

†Excluding kidney fat;
*As percentage of carcass weight including kidney fat

Table 2.6
Composition of lamb, dairy goat and Angora x dairy goat carcasses of 20.5kg
(Mowlem, 1988)

2.3.3 Carcass conformation and joint distribution

Carcass conformation is determined primarily by the shape and thickness of the muscles and is therefore mainly dependent on the maturity of the animal at slaughter. Conformation may also relate to the level of subcutaneous fat cover, particularly when assessed on the live animal, and is therefore also influenced by the level of nutrition and total fatness of the animal (Kirton and Pickering, 1967). Despite having lean to bone ratios equivalent to those of lamb carcasses, goats have a comparatively poor carcass conformation, with greater carcass and leg length but shallower carcass depth, resulting in a less compact carcass (Fehr *et al.*, 1976; Naudé and Venter, 1977; Owen and Norman, 1977). This is mainly attributable to the later maturity of goats, who continue to show growth in the head and limbs at a more advanced age than sheep (Owen *et al.*, 1977). An exception is the more muscular South African Boer goat which has a carcass conformation similar to that of the sheep but with a fat distribution

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which is still typical of the goat (Naudé and Venter, 1977; Owen *et al.*, 1978). The low carcass fat content and poor subcutaneous fat cover of goats compared with sheep at similar stages of maturity also contributes to the poorer conformation of the goat carcass when assessed by the same criteria as sheep carcasses (Fehr *et al.*, 1976; Thonney *et al.*, 1987b).

Carcass conformation is frequently described in terms of the relative contributions of the various joints to the whole. The most valuable commercial joints are the hind leg and the loin, followed by the shoulder, since in the mature carcass they contain the highest proportion of lean and the lowest proportion of dissectible fat (Gaili *et al.*, 1972; Owen *et al.*, 1978). Average values are difficult to compare due to the diversity of jointing techniques used, but in general the leg contributes 29% of carcass weight in the goat, the loin contributes 8% and the shoulder 44% (Gall, 1982; Butler-Hogg and Mowlem, 1985). The individual joints contribute similar proportions to carcass weight over a wide range of liveweights (Butler-Hogg and Mowlem, 1985) but vary depending on the stage of maturity of the carcass (Pálsson, 1939). The shoulder and leg, being early maturing joints, generally decrease in proportion with increasing carcass weight, while the later maturing loin tends to increase in proportion (Fehr *et al.*, 1976; Owen and Norman, 1977).

Differences between goats and sheep have been detected in both joint proportions and in the distribution of carcass tissues between the joints. Owen and Norman (1977) found that, with the exception of the loin joint, Botswana male castrate goats had greater proportions of all joints than Botswana male castrate sheep at comparable ages (Table 2.7). Similarly, Gaili and Ali (1985a) found that muscle development in the male Sudan desert goat was greater than that in the sheep in the forelimb (21.6% *v* 19.9%) and the neck plus thorax (35.7% *v* 34.5%) while the *M. psoas major* was better developed in the sheep than in the goat (1.8% *v* 1.4%) when compared at an equally adjusted carcass weight. These differences are probably another reflection of the later maturity of goats rather than an absolute species difference in joint development. However Thonney *et al.* (1987c) found that although British feral goats excelled in total muscle proportion relative to sheep of equal maturity, their muscle weight distribution was less attractive because the goats had a lower proportion of muscle in the higher priced cuts.

| Joint | % of carcass weight | | | |
| | Goat | | Sheep | |
	Milk tooth	6 tooth	Milk tooth	6 tooth
Neck	10.2	9.6	9. 0	9.5
Shoulder	20.2	19.6	16.3	15.7
Thorax	20.2	20.9	19.8	20.4
Loin	23.2	24.2	25.1	26.3
Leg	24.0	22.8	22.8	21.1

Table 2.7

Joint distribution of carcasses of Botswana male castrate goats and sheep
(Owen and Norman, 1977)

Owen and Norman (1977) and Hogg *et al.* (1989) found significant differences in joint proportions between different breeds of goat of comparable liveweights, but these differences were largely explained by the different mature liveweights of the breeds in question.

2.4 Prediction of carcass composition

Due to the time required and the expense of dissecting whole or even half carcasses, sample joints whose tissue proportions have a high correlation with the tissue proportions of the entire body or carcass are often used to predict whole carcass composition. Regression equations have now been derived for most breeds of domestic animal which enable the prediction of whole body composition from a knowledge of the composition of a single joint or a limited number of joints, alone or in conjunction with other carcass and non-carcass measurements (Barton and Kirton, 1958; Butterfield, 1965; Kempster *et al.*, 1976).

To be a useful predictor the sample joint must not only provide an accurate reflection of carcass composition, but must also be obtained with minimal damage and loss of value to the carcass and be relatively simple and quick to dissect (Naudé & Hofmeyr, 1981).

Highly significant correlations, with coefficients approaching 1.0, have been found between the weights of all tissues in the joint and the total weight of the same tissue in the carcass for most commercial joints in the lamb (Pálsson, 1939; Barton and Kirton, 1958) and the goat (Morand-Fehr *et al.*, 1977; Naudé and Venter, 1977). The most accurate estimates of whole carcass composition were obtained from the leg and the loin, with more precise estimation being achieved through the use of the two joints in combination. When the time taken to dissect the joints, ease of removal from the carcass and cost were considered, the leg was found to be the most appropriate predictor.

Non-carcass components may also be useful predictors of carcass composition, particularly when the ease with which they are obtained and their low cost is considered. Thus, in goats, the weight of caul fat and total abdominal fat were highly correlated with total carcass and body fat (Gall *et al.*, 1972; Morand-Fehr *et al.*, 1977) and the total weight of bone in the carcass was accurately predicted by the weight of the cannon bone in the lamb (Pálsson, 1939; Timon and Bichard, 1965) or the four feet in the goat (Morand-Fehr *et al.*, 1977). The weight of the feet was also a good predictor of carcass muscle (Morand-Fehr *et al.*, 1977) as was the weight of the diaphragm and of the forelimb muscles in the goat (Gall *et al.*, 1972).

A criticism of many of these predictors is that in view of the wide range of carcass weights used to obtain the correlations between the composition of the predictor and that of the whole carcass, it is likely that the high coefficients obtained were due to weight-weight relationships and may not apply where a change in carcass composition is not accompanied by a change in carcass weight (Gall, 1982).

2.5 Growth rate and feed conversion efficiency

The majority of research on the growth of goats has been performed in the tropics and sub-tropics with goats reared under conditions of poor management and nutrition. Consequently growth rates are variable and low, ranging between 60 and 116g/day (Wilson, 1958a; Devendra, 1966; Wilson 1976). Dairy goats reared in temperate regions under more favourable conditions have achieved growth rates of between 150 and 210g/day (Skjevdal, 1974; Robstad, 1976; Fehr *et al.*, 1976). Growth rates of the Angora goat are generally poor due to the extensive management systems used in the production of mohair, and rarely exceed 50 to 100g/day (Miller *et al.*., 1943; Calhoun *et al.*, 1988a, b). Furthermore, when compared with lambs reared under equivalent conditions the growth performance of most breeds of goat, including the Angora, is poor and is associated with a lower efficiency of feed conversion (Table 2.8). Consequently when species comparisons are made at equal ages, goats are generally less mature than sheep which explains their poorer carcass composition and conformation.

One of the major influences on the growth rate of goats is their mature size. When composition, efficiency and rate of growth of large and small cattle breeds were compared over the same slaughter weight range, genetically larger animals were leaner and grew faster and more efficiently than genetically smaller animals (Thonney *et al.*, 1981), but when mature size differences in sheep breeds were allowed for, there was little difference in efficiency or rate of growth at the same stage of maturity because the composition of gain was similar (McClelland *et al.*, 1973; Butterfield *et al.*, 1983; Thompson and Parks, 1983). The wide variety in mature size of different goat breeds (Table 2.2) therefore probably contributes to the diversity of growth rates reported in the literature and the poorer growth performance of the Angora compared with the larger dairy breeds. Similarly, most breeds of goat have a smaller mature body weight than sheep which may explain the poorer growth performance of the goat in species comparisons. Furthermore, since comparisons are generally made over equal liveweight ranges the smaller goat is at a disadvantage since it will be more mature than the sheep, and growth rate and efficiency tend to decline with maturity (Brody, 1945; Gallagher and Shelton, 1972). Hence male castrates of the large Boer breed had a mean

growth rate comparable with that of the Merino sheep between 10 and 40kg liveweight (Naudé and Venter, 1977). However, Thonney et al. (1987a) compared the growth rate and efficiency of equally mature goats and sheep and found that goats grew more slowly than expected relative to their mature weight and had a lower feed conversion efficiency than the whole trial average, indicating a real species difference in growth potential.

Low efficiency may be attributable to poorer nutrient digestibility in the goat compared with the sheep. Mohammed and Owen (1980) recorded dietary energy digestibilities of 53.1% and 55.3% in goats and sheep respectively when they were fed a pelleted ration at rates to maintain a constant liveweight and Gallagher and Shelton (1972) reported poorer organic matter digestibility in young Angora goats (55.4%) compared with young sheep (60.2%). They also observed species differences in the partitioning of energy for body tissue and fibre growth. Young sheep were 1.5 times more efficient at converting feed to liveweight gain than young goats, while goats were 3.2 times more efficient at converting feed to fibre. High maintenance requirements in the goat, relative to the sheep, may also contribute to their high feed conversion ratios. Mohammed and Owen (1980) found a metabolizable energy requirement for maintenance of $0.43MJ/kgM^{0.75}$ per day in goats and $0.30MJ/kgM^{0.75}$ per day in sheep. In support of this, when higher rates of gain have been achieved better efficiencies of between 2.4 to 5.4 grammes of feed per gramme of gain were recorded (Table 2.8).

Significant improvements in growth rate and efficiency have been achieved with increases in both dietary energy and protein. Shahjalal et al. (1992) found that by increasing the daily protein intake of Angora wethers from 83 to 145g/day their growth rates improved from 48 to 79g/day and their feed conversion ratios decreased from 16.5 to 10.2 grammes of dry matter per gramme of liveweight gain. By increasing the daily energy intake of the goats from 7.6 to 9.9MJ ME their growth rate was further increased to 116g/day and their feed conversion ratio was further improved to 7.3 grammes of dry matter per gramme of liveweight gain. These values are still poor when compared with average figures for sheep. McGregor (1985a) concluded that a major limitation to rapid growth rates in goats is their low energy intake, which is generally about 1.5 to two times maintenance compared with four times maintenance

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in the sheep. Angora goats fed grain-based diets *ad lib.* achieved a maximum intake of only 2.3 times maintenance (McGregor, 1984a) while sheep offered a similar diet consumed three times maintenance (Fraser and Orskov, 1974).

Castration of male kids has been shown to reduce their feed intake, rate of gain and feed conversion efficiency (Owen and Mtenga, 1980; Babiker *et al.*, 1985) but mature, entire males lost their advantage over castrates by the exhibition of strong sexual activity which caused their growth almost to cease (Louca *et al.*, 1977).

Source	Breed/species	Sex	Weight range (kg)	Growth rate (g/day)	F. C.E. (g feed/g gain)†
Miller et al. (1943)	Angora goat	C	23 - 32	86	9.7
			28 - 34	54	14.5
			35 - 42	73	12.9
	Rambouillet lamb		28 - 42	141	7.0
Fehr et al. (1976)	Alpine goat	M	3 - 16	209	2.4
			3 - 34	176	3.8
Louca et al. (1977)	Damascus goat	M	21 - 47	240	4.8
			47 - 57	100	12.9
		C	18 - 40	210	5.1
			44 - 53	110	11.1
		F	18 - 37	190	5.4
Owen & Mtenga (1980)	British Saanen goat	M	Weaning - 25	222	3.4†
			25 - 37	185	5.9
		C	Weaning - 25	183	4.1
			25 - 37	234	5.5
Naudé & Hofmeyr (1981)	South African Boer goat	M+F	9 - 26	200	3.9
Throckmorton et al. (1982)	Angora goat	C	19 - 30	81	8.2
	Merino sheep		19 - 35	119	6.2
Gaili & Ali (1985a)	Sudanese desert goat	M	16 - 19	43	9.3
	Sudanese desert sheep		24 - 31	125	5.9

†Units expressed in terms of feed fresh matter except where indicated, when dry matter is used.

Table 2.8

Growth rates and feed conversion efficiencies of goats and sheep

2.5.1 Compensatory growth

Compensatory growth is defined by McGregor (1985a) as "the rapid growth following a long period of weight loss or weight stasis" and by Wilson and Osbourn (1960) as "a rate of growth greater than that which is normal in animals of the same chronological age". The growth rate is usually no greater than that achieved by unrestricted animals of the same physiological age but in some cases has been shown to exceed the normal unrestricted growth rate (Murray and Slezacek, 1976; Stamataris *et al.*, 1991). Animals which have undergone compensatory growth have often achieved their normal mature body size or the required slaughter weight (Waters, 1909; Osborne and Mendel, 1915). The phenomenon was first demonstrated by Osborne and Mendel (1915) in rats and has since been shown to occur in pigs (McMeekan, 1940c; Stamataris *et al.*, 1991), sheep (Pálsson and Vergés, 1952) and cattle (Waters, 1909; Eckles and Swett, 1918). Many experiments have, however, reported a failure to recover from undernutrition resulting in permanent stunting of the animals involved (Eckles and Swett, 1918; McCay *et al.*, 1939). Variable results have also been reported from the few studies of undernutrition in the goat. Wilson (1958a) showed compensatory liveweight gain in the East African dwarf goat and McGregor (1984b) observed that nutritionally deprived yearling Angora wethers could 'catch up' lost liveweight gain under suitable conditions of nutrition, but McDowell and Bove (1977) concluded that goats do not exhibit compensatory growth.

The factors affecting an animal's ability to recover from the effects of undernutrition and the probable mechanisms of action of compensatory growth have been reviewed by Wilson and Osbourn (1960). The degree of compensatory growth exhibited is dependent upon the severity of undernutrition, which varies from weight loss, a period of weight stasis or very low weight gain. Eckles and Swett (1918) found in dairy heifers that if the restriction was too severe the mature size was permanently stunted. The duration of the period of undernutrition may also affect the animal's ability to recover. Rats maintained at constant body weight for 1000 days were permanently stunted (McCay *et al.*, 1939) while restriction for only 500 days allowed them to achieve their normal mature size upon realimentation (Osborne and Mendel, 1915).

The maturity of the animal when undernutrition is imposed also appears to be important; the less mature the animal the less compensatory growth can be expected (Black *et al.*, 1940; Bohman, 1955; Allden, 1970; Morgan, 1972). Similarly the rate of maturity of a breed affects its ability to recover from undernutrition. Joubert (1954) found that periodic undernutrition had a more severe effect on the early maturing Shorthorn breed of cattle than on the late maturing Afrikander breed. In this respect the goat, being a relatively slow growing and late maturing species, might be expected to recover well from undernutrition compared with other domestic species.

The pattern of realimentation has also been shown to affect the recovery of underfed animals. Bohman (1955) and Heinemann and Van Keuren (1956) found that the higher the plane of nutrition upon realimentation the more rapid and the greater the recovery in weight of cattle. Finally the nature of the nutrient restricting growth may affect the ability of the animal to recover completely. Wilson and Osbourn (1960) concluded that very severe protein restriction may have a more harmful effect than very severe energy restriction since there is little reserve protein in animals.

There have been several attempts to explain the mechanisms of action of compensatory growth. Ragsdale (1934) suggested that undernutrition disturbs the normal relationship between chronological and physiological age such that when an animal is realimented it grows at a rate appropriate to its physiological age rather than to its chronological age (Winchester and Ellis, 1957). As animals approach maturity their growth enters the self-retarding phase and is limited by inhibiting factors such as availability of nutrients and lack of space (Pomeroy, 1955). Consequently immature animals whose growth has been retarded have a greater growth potential following realimentation than unrestricted animals of the same age but greater maturity. This proposal is sufficient to account for the abnormally rapid growth *relative to age* which is generally observed (McMeekan, 1940c; Pálsson and Vergés, 1952), but does not explain why compensatory growth often *exceeds* the growth rate of unrestricted animals over a comparable liveweight range (Wilson, 1958a).

Several studies have indicated that compensatory growth is mainly explained in terms of the

increased gut fill which accompanies realimentation, with no increase in the rate of body tissue gain (McMeekan, 1940c; Thornton *et al.*, 1979). However Taylor *et al.* (1957) found significantly greater carcass gains in realimented cattle compared with cattle grown at a constant rate over the same period, and Murray and Slezacek (1976) found that compensatory liveweight gain in sheep was not associated with an increase in the weight of the contents of the alimentary tract. This study revealed no effect of compensatory liveweight gain on the composition of the dissected carcass but Pomeroy (1955) suggested that compensatory liveweight gain is partly due to a replacement of fat in the adipose tissues which have been depleted during the restriction period i.e. changes in the differential deposition of fat. Few experiments have been able to demonstrate a significant effect of compensatory liveweight gain on body and carcass composition which were not attributable to variation in fatness. Thus animals reared to the same stage of maturity and compared on a fat-free basis had identical carcass composition whether or not they had undergone a period of undernutrition (Wilson, 1958a, b, 1960; Elsley *et al.*, 1964).

Sheehy and Senior (1942) suggested that restricted cattle make greater weight gains upon realimentation than unrestricted animals fed *ad libitum* on the same ration because, being smaller and less active, their maintenance requirements are less than those of unrestricted controls. The same study revealed a marked increase in the appetite of animals during realimentation which was later confirmed by Winter (1971) in sheep and by Stamataris *et al.* (1991) in pigs. This may be related to the early maturing nature of the alimentary tract which is consequently only slightly retarded by undernutrition (McMeekan, 1941; Pálsson and Vergés, 1952; Wilson, 1954a).

Compensatory growth has no adverse effect on the eating quality of meat in either sheep (Winter, 1970) or cattle (Morgan, 1972) despite the advanced age of the realimented animals. Since the unfavourable quality of goat meat has been associated with its poor subcutaneous fat cover (Smith *et al.*, 1978) it is possible that if compensatory growth in the goat is associated with an increased relative rate of fat development this could actually improve the quality of the meat produced.

2.6 Nutrient requirements of the Angora goat

There is little direct data concerning the nutrient requirements of goats, particularly the Angora. The few existing publications are based on limited information derived from dairy goats or extrapolated from lamb data (Huston *et al.*, 1971; National Research Council (N.R.C.), 1981) and contain no information concerning the effects of level of nutrition on the composition of liveweight gain. The N.R.C. (1981) has developed recommendations for the nutrient requirements of goats based on pooled means of experimental data derived from a variety of breeds (Table 2.9). The values for protein requirements were determined from reports which had computed protein requirement as a ratio to energy requirement, rather than through the use of nitrogen balance studies, since adult goats can adjust their nitrogen output and reach equilibrium by varying the quantity of urea recycled to the rumen, particularly at lower levels of nitrogen intake. Nitrogen balance studies are therefore of questionable value in the goat. The mean protein to energy ratio for maintenance and growth was calculated as 9.5g crude protein / MJ ME.

Function	Energy	Crude protein
Maintenance only	0.42MJ ME/kg$^{0.75}$	4.15g CP/kg$^{0.75}$
Maintenance plus low activity.	25% increment	25% increment
Maintenance plus medium activity	50% increment	50% increment
Maintenance plus high activity	75% increment	75% increment
Growth	0.03MJ ME/g gain	0.28g CP/g gain
Fleece growth	0.125MJ ME/kg fleece	4.25g CP/kg fleece

Table 2.9
Nutrient requirements of the goat (N.R.C., 1981)

The value for the maintenance energy requirement of goats reported here is comparable with figures provided for sheep of between 0.36 and 0.435MJ ME/kg$^{0.75}$ (N.R.C., 1975; A.R.C., 1980; A.D.A.S., 1986). A similar value of 0.43MJ ME/kg$^{0.75}$ for British Saanen castrate goats was reported by Mohammed and Owen (1980) who recorded a lower maintenance requirement of 0.30MJ ME/kg$^{0.75}$ for Suffolk x Scottish halfbred wether sheep.

The value for the energy requirement for growth in goats (Table 2.9) is the same as that given by A.R.C. (1980) for sheep but greater than that of 0.02MJ ME/g gain provided by N.R.C. (1975).

The nutrient requirements for fibre production were based on factorial calculations by Huston *et al.* (1971). They suggest an optimum protein to energy ratio of up to 12g crude protein/MJ ME. When the digestibility of the protein is considered, this value is slightly lower than the optimum value reported for wool production in the sheep by Kempton (1979) which is 12g digestible protein/MJ ME. This may be due to the greater efficiency of conversion of feed to fibre of the Angora goat compared with the sheep (Gallagher and Shelton, 1972) or to the greater importance of fibre diameter in the Angora goat, which increases with increasing protein content of the diet (Shelton and Huston, 1966).

Subsequent to the preparation of this thesis new recommendations of the nutrient requirements of goats were proposed by the AFRC's Technical Committee on Responses to Nutrients, based on a review of published research and information in the field of goat nutrition (AFRC, 1993). Based on these recommendations, tables of ME and metabolisable protein requirements of housed, castrate male kids are presented in AFRC (1993). They include allowances for mohair fibre production and for liveweight gains of between 0 and 200g/d.

Recommendations of dry matter intake are variable, ranging from $185g/kg^{0.75}$ in fast growing kids and lactating does to $56g/kg^{0.75}$ in slow growing mature goats (Huston *et al.*, 1971; N.R.C., 1981; Sauvant *et al.*, 1991). Cooper (1989) recommends a voluntary dry matter intake of $80g/kg^{0.75}$ for goats. As for other domestic species the voluntary feed intake of goats varies according to the diet (McGregor, 1984a). Goats appear to have a greater preference for a higher fibre content of the diet than lambs (Wilson *et al.*, 1975) and are more efficient than sheep and cattle at digesting low quality feeds, but on better quality feeds there is no difference between species in either dry matter or nitrogen digestibility (Devendra, 1978; Doyle and Egan, 1980). The preference of goats for a high fibre content of the diet

limits their voluntary feed intake and may partially explain their poor growth performance relative to sheep (McGregor, 1984a).

2.7 Mohair fibre production in the Angora goat

The mohair fleece consists of two distinct fibre types. Mohair fibres are produced by the secondary skin follicles and are long, lustrous, elastic and round in cross-section. They are analogous to the downy undercoat, or cashmere fibres, produced by all other breeds of goat but, unlike cashmere, mohair is not seasonally shed but grows continuously. The mohair fleece is therefore shorn twice per year while cashmere is combed from the outer coat or guard hairs. Kemp fibres are vestigial guard hairs which are produced by the primary skin follicles of the Angora. They are brittle, non-elastic, chalky white in appearance, and oval in cross-section. They are also much shorter than mohair fibres and are further characterised by a continuous air filled medulla which affects their ability to take up dye. The problem of kemp in mohair has been reviewed by Tiffany-Castiglioni (1986). Mohair is a relatively coarse fibre with mean diameters ranging from 15 to 45μm while cashmere generally varies from 12μm to no more than 19μm. However the yield of mohair is much greater at approximately 2.5kg per shear compared with 125g from a single harvest of cashmere (Ryder, 1986). The two fibre types also differ greatly in their financial value. In the UK the price received for mohair in 1990-1991 varied between £2.50-£9.00 per kilogram while that for cashmere was nearer £85-£100 per kilogram (SAC, 1991).

2.7.1 Fibre characteristics of economic importance

The value of the mohair fleece is influenced by several characteristics, the most important being fibre diameter, staple length, clean fibre yield and the proportion of medullated fibres. This last category falls outside of the scope of this study and will not be discussed further.

Fibre diameter is the major factor influencing the price received for mohair since it determines the type and quality of the end product for which the fibre may be used. The finest and most valuable fibre is produced by kids and young goats, has a diameter in the range 24 - 32μm and a minimum length of 75 - 100mm. This is reserved for fashion fabrics and fancy yarns. Coarser fibre, obtained from older animals, may reach 46μm in diameter and is used in upholstery materials, carpets and curtains (Westhuysen, 1982; Thelwall, 1988).

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Staple length varies little and is primarily a reflection of the length of the inter-shearing period (Shelton, 1961). The price for mohair in the U.K. is influenced very little by the length of the fibre, provided it is longer than 7.5cm. Fleeces shorter than this are difficult to process and realise about 80% of the price of longer fleeces (Wilkinson and Stark, 1987). Therefore there is little economic justification for shearing more than twice a year, when the fleece is about 12cm long.

The income from an individual animal ultimately depends on the mass of clean mohair produced. Mohair production (mass) increases from birth and peaks at approximately three or four years of age, whereafter it declines gradually (Figure 2.1). Values for the mass of greasy fleece produced per goat per year vary according to the country of origin, sex, age and management of the goat (Table 2.10). The clean yield is calculated by scouring the fleece according to commercial practice to remove grease, dirt, dust and sweat. Values vary little and are normally in the region of 75 - 88% of greasy fleece weight (Bassett, 1966; Westhuysen *et al.*, 1985).

Country of origin	Sex	Age	Greasy fleece weight (kg)	Source
South Africa	-	-	4.35	
U.S.A.	-	-	3.70	
Turkey	-	-	2.25	Westhuysen (1982)
Argentina	-	-	1.00	
Lesotho	-	-	0.75	
South Africa	F	yearling	3.17	
	F	adult	4.71 - 4.80	
Turkey	F	yearling	1.49	Yalcin (1982)
	F	adult	2.48 - 3.13	
U.S.A.	F	yearling	3.57 - 3.83	
	F	adult	5.39 - 5.57	
South Africa	-	kid	1.0 - 2.0	
	F	adult	4.0 - 5.0	Westhuysen, *et al.*
	C	adult	5.0 - 6.0	(1985)
U.S.A.	-	kid	1.2	
	-	adult	2.7 - 5.0	Ryder (1986)
U.K.	-	kid	1.2	
	-	yearling	1.8	Nix (1990)
	-	young goat	2.2	
	-	adult	3.0	

† Kid values represent one shear at 6 months of age. Goats from Turkey, Argentina and Lesotho are shorn only once per annum. U.K. values are per shear. All other values represent the sum of two shears per annum.

Table 2.10

Average production of mohair per goat per year†

Date	Mohair production per goat (kg)*
1890 - 1910	1.79
1950 - 1960	3.18
1975 - 1980	4.02

* Average for the whole period (Westhuysen, 1982)

Table 2.11

Average production of mohair per goat in South Africa from 1890 to 1980

2.7.2 Factors affecting fleece and fibre characteristics

The main production parameters such as follicle density, ratio of secondary to primary follicles (S/P-ratio), fibre diameter, staple length, yield and body mass are determined genetically. Heritabilities are variable but generally moderate to high. Estimates for greasy fleece weight range between 0.13 to 0.40, fibre diameter varies from 0.11 to 0.19 and S/P ratio is generally greater than 0.25 (Yalcin, 1982; Westhuysen et al., 1985). It is therefore possible to make genetic progress through accurate selection to produce high yielding breeding stock with little or no kemp. Significant improvements in fleece production have been achieved in South Africa during the last century (Table 2.11).

The age of a goat has a significant effect on the yield and quality of its fibre. At birth the Angoras coat consists mainly of long kemp fibres, since the ratio of mohair producing secondary follicles to kemp producing primary follicles (S/P) is low and the secondary follicles are mainly inactive. During the first three to four months after birth the mohair producing follicles mature and become productive and the S/P ratio rises. Many of the primary follicles shed their kemp fibres during this period and thereafter are less active (Tiffany-Castiglioni, 1986). Consequently, after the first six months of life the coat consists mainly of mohair with a kemp content rarely exceeding 4% (Westhuysen et al., 1985). From about three months of age changes in the activity of the secondary follicles result in further changes in fibre diameter and mohair mass with increasing age. Shelton (1961) reported that fibre diameter increased from an average of 24μm at six months to 46μm for adult animals up to 11 years of age, but staple length showed little change with age and grew at an average rate of approximately 20 to 25mm per month (Figure 2.1). Mohair mass increased rapidly from birth up to three or four years of age after which it gradually decreased in adults up to 11 years of age. Body mass increased with age up to eight years and then stabilised. Consequently kg mohair/kg body mass peaked at about two years of age and rapidly declined thereafter. Shelton concluded that, taking into account the effect of fibre diameter on price, mohair production reaches an economic peak at approximately 18 to 24 months of age.
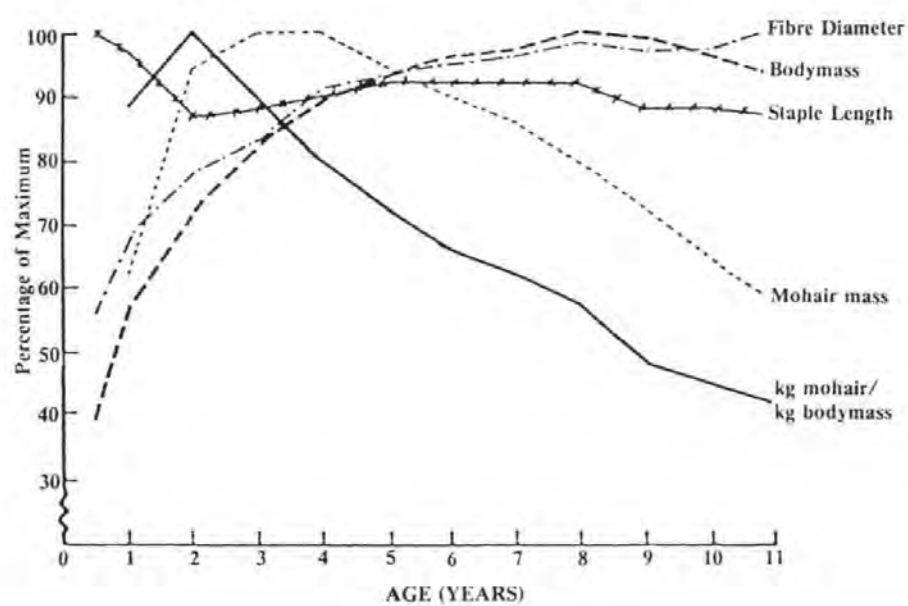
Figure 2.1

The effect of age on fleece and fibre characteristics in the Angora goat (Shelton, 1961)

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It is possible that nutrition and liveweight rather than age *per se* are the major determinants of mohair mass and fibre diameter. McGregor (1985b) concluded that poorer fed and smaller, but not necessarily younger, goats produced finer mohair than better fed and larger Angoras. Westhuysen *et al.* (1985) reported that fibre diameter was significantly correlated with body mass and that a similar positive correlation existed between fleece weight and fibre diameter and hence also between fleece mass and body mass. Calhoun *et al.* (1988a) also found a positive correlation between greasy fleece weight and average shorn body weight.

Bassett (1966) showed that for Angoras aged 1.5 to 4 years average greasy fleece weights were 1 to 2kg lighter at the Spring shearing than in the preceding Autumn, with lower yields and therefore lower clean fleece weights. Staple length was also shorter in the Spring, indicating slower fibre growth in the Autumn/Winter than in the Spring/Summer. However, fibre diameter for all groups was greater in the Spring than in the Autumn and was associated with the increase in age/body weight rather than indicating a seasonal effect. Kids shorn at six and 12 months of age produced heavier greasy and clean fleeces in the Spring although, consistent with the other groups, staple length values were lower and fibre diameter was greater. Thus it would appear that for this age group the seasonal effect was existent but masked by the age/body weight effect.

Fibre production is influenced by nutritional factors such as protein and energy. Shelton and Huston (1966) found a direct increase in clean fleece weight in yearling billies, from 3.3 to 4.6kg, as the level of protein supplementation increased from 19.1 to 44.1g per day. Fibre diameter also increased from 35.8 to 38μm but there was no effect on staple length. Westhuysen *et al.* (1985) reported that protein intake had a greater limiting effect on fleece yield in Angora kids than energy intake. This has been confirmed by more recent studies. Deaville and Galbraith (1990) found that young goats receiving an average ME intake of 8.2MJ per day yielded 20% more fibre when their crude protein intake was increased from 75 to 141g per day. Fibre diameter increased from 31.8 to 35.5μm on the higher level of protein intake. Over a similar range of protein intakes Shahjalal *et al.* (1990) observed no further effect on either fleece growth or fibre diameter by increasing the daily energy ration from 8.1 to 9.45MJ ME.

However, several studies have observed significant quadratic effects of both energy and protein intake on fibre growth when the other nutrient remained constant which suggested that there is an optimum energy to protein ratio for fibre growth (Calhoun *et al.*, 1988a; Shahjalal *et al.*, 1991). These studies suggest that the optimum ratio lies between 14.5 and 17g crude protein per MJ ME, a range somewhat higher than the optimum value of 12g crude protein per MJ ME recommended earlier by Huston *et al.* (1971). Shahjalal *et al.* (1991) also showed that fibre diameter followed a similar pattern to fleece growth, increasing from 29.8 to 36.1μm with increasing protein intake but decreasing again to 33.6μm at the highest level of intake.

From the limited information available it would seem that increased yields of mohair achieved by means of nutrient manipulation are obtained via an increase in fibre diameter and not by increasing staple length. Consequently, the benefits of higher yield must be balanced with the penalties incurred by producing coarser fibre.

3 Trial 1. The effects of level of nutrition on mohair fibre characteristics, liveweight gain and differential growth of the British Angora wether goat

3.1 Rationale and objectives

The volatile nature of the U.K. mohair industry has necessitated Angora goat producers to devise systems of management which will enable them to optimise their income from the production of both meat and mohair. The finest and most valuable fibre is obtained from goats of between six and 24 months of age. It is probable that the optimum carcass quality will also be reached within this age range, thus presenting the producer with a conflict of interests; current commercial practice dictates that Angora goats are reared on a low plane of nutrition in order to maintain fibre quality. It is unlikely that they will approach their full growth potential under these conditions, but improvement of the meat carcass by nutritional means is likely to have deleterious effects on fibre quality since energy and protein supplementation improve fleece yield by increasing the fibre diameter. This greater diameter reduces the value of the fibre and incurs high price penalties. Furthermore, the nutrient requirements of the growing Angora goat are poorly understood, particularly under U.K. conditions. Information is needed concerning the differential growth of carcass components and the relationship, if any, between the development of the carcass with age/increasing liveweight and the changes that occur in fleece yield and quality with advancing maturity of the goat and increasing plane of nutrition.

The objectives of this experiment were therefore to determine the differential growth patterns of the British Angora goat from six months of age to maturity, to investigate the effects of plane of nutrition on the allometric relationships, and to determine the effects of age and plane of nutrition on the relationships between carcass composition and fleece characteristics. The male castrate was selected for this study since this constitutes the major source of meat, being generally redundant after two years of age when fibre quality begins to decline. Sequential slaughter and carcass dissection were performed at the predetermined ages of six, 12, 18 and 24 months to coincide with the commercial practice of shearing Angora goats at six monthly intervals.

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3.2 Materials and methods

3.2.1 Trial design

The trial was a 3 x 4 factorial design. The variables were level of nutrition (high, medium and low) and age at slaughter (6, 12, 18 and 24 months) with six replicates per treatment group (Table 3.1).

Level of nutrition	Age at slaughter (months)				Feeding regime
	6	12	18	24	
High	6H/M	12H	18H	24H	*Ad libitum* goat pellets
Medium		12M	18M	24M	Rationed goat pellets
Low	6L	12L	18L	24L	Commercial - grass based

Table 3.1

Summary of treatment groups in Trial 1 and their codes

A total of 66 goats were allocated to only 11 treatment groups since the restriction was not applied to the medium group until six months of age. Treatment groups 6H and 6M were therefore represented by the same six animals.

3.2.2 High and medium levels of nutrition

(i) Experimental animals

Fifty Texan x New Zealand type British Angora wether kids, born February - April 1990, were purchased from a single lowland farm at 15 weeks of age. This number allowed 42 to be allocated to seven treatment groups, six per group, plus an additional eight kids as reserve animals in case of death or ill health in the early months of the experiment. The kids were weaned immediately prior to purchase. On arrival at the trial site, the 50 kids were allocated to six pens for ease of management, according to their age and entry weight, but they were not

pens for ease of management, according to their age and entry weight, but they were not allocated to different levels of feeding until they were six months of age.

(ii) Housing

The goats were housed throughout the trial in an open fronted building, containing six pens 5m x 5m. They were bedded on barley straw, replenished as required, and had free access to fresh water and a salt lick. Since wether kids are susceptible to the development of urinary calculi when reared on concentrate diets, daily water consumption per pen was monitored as a management aid, using Kent P.S.M. - L water meters (Kent Meters Ltd., Luton, Beds.). The feed troughs were mounted on adjustable brackets and raised 0.5m from the ground, on the outside of the pen, to prevent fouling of the feed and allow easy collection of refusals. The trough height was adjusted regularly to allow for the accumulation of bedding and increasing height of the goats. Each pen was provided with strutted ramps and large logs to encourage a low degree of activity in the goats.

(iii) Kid health

The kids were drenched with 5ml of Oramec (M.S.D. - Agvet, Hoddesdon, Herts.) three weeks before delivery to the trial site and again immediately before delivery. Following this course of treatment they were considered to be completely free of intestinal worms and not treated again for the remainder of the trial. They were vaccinated against Pasteurella and Clostridia with 2ml Tasvax Gold (Coopers Animal Health Ltd., Crewe, Cheshire) and 1ml Pastacidin (Hoescht U.K. Ltd., Milton Keynes, Bucks.) immediately before delivery. They received their second vaccination six weeks later and a booster dose after 12 months. Their feet were routinely checked and trimmed every four to six weeks, and belly fibre was kept trimmed close to the skin to prevent urine burns which are common to Angora goats. Ovipor (Rycovet Ltd., Glasgow) was used for the prevention and treatment of louse infestations as required.

After approximately five weeks on trial many of the younger, more recently weaned animals

showed signs of coccidial infection. Scouring kids were removed from the creep feed, offered only hay and treated with 7.5ml Vesadin (R.M.B. Animal Health Ltd., Dagenham, Essex). One kid had to be destroyed, but was replaced with another from the same source since it was early enough in the trial to do so. The rest recovered and were returned to the pre-determined level of feeding over three weeks.The disease returned approximately two weeks later so all kids were treated with 3ml Bimalong (Bimeda U.K. Ltd., Liverpool) for three days. A coccidiostat (Deccox, 100ppm decoquinate, R.M.B. Animal Health Ltd.) was included in the pelleted feed for four weeks and the pens were cleared and disinfected. Another kid had to be destroyed and one died. Surviving kids which had been seriously affected by the disease were designated spare animals to avoid the possibility of including stunted animals in the trial. One kid died of asphyxiation after becoming trapped in a hay rack during this period. Another died of urolithiasis at 11 months of age. There were no further problems with ill health.

(iv) Diets

The kids were weaned onto lamb pellets containing 160g crude protein/kg DM (Lydney and District Farmers, Dean, Glos.) at four months of age. On arrival at the trial site they were transferred to Dalgety lamb creep feed (code no. 281, Dalgety Agriculture Ltd., Lifton, Avon) which contained 12.5 MJ ME/kg DM and 160g crude protein/kg DM. Group intakes of the creep feed were increased over a three week period until all of the kids were consuming an amount calculated to allow maintenance plus 150g daily liveweight gain when fed with hay or barley straw, as available. With the exception of those periods of ill health when it was necessary to restrict feed intakes, feeding continued at this level for all kids until they were six months of age, when the first treatment group, 6H/M, was slaughtered.

At six months of age the remaining 40 kids were introduced to a pelleted complete diet containing 8.9 MJ ME/kg DM and 114g crude protein/kg DM which was formulated and produced by Dalgety Agriculture Ltd., Lifton, Avon (Appendix I). A review of the literature had concluded that a diet of this specification would allow maintenance plus approximately 90g daily liveweight gain on *ad libitum* intakes, which are generally of the order of 80g

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DM/kg metabolic body size. When all of the kids were readily consuming the complete diet, the six pens were each allocated to one of two treatments on the basis of mean pen liveweight. For the remainder of the trial the three pens allocated to a high level of nutrition were offered the complete diet *ad libitum*, on a group-fed basis. Any feed refused after 24 hours was collected, weighed and discarded. Fresh feed was offered at 110% of the previous days intake, initially as a single morning feed but due to the limitations of trough space and the tendency of the goats to push the feed out of the troughs it was eventually offered as two equal feeds, morning and afternoon.

The three pens allocated to the medium level of nutrition were group fed 80% of the *ad libitum* intake, calculated per unit of metabolic body size on a weekly basis. This level of intake was estimated to allow maintenance plus approximately 50g daily liveweight gain.

The kids were weighed weekly, using a weigh crate (G.H.L. Products, Crewe, Cheshire) fitted with a Salter Universal weigh head with 200kg load cell and a definition of 0.1kg, to determine daily liveweight gain and feed intake per kg liveweight$^{0.75}$. Since it was not possible to weigh the *ad libitum* fed kids empty, all kids were weighed approximately one hour after the morning feed so that liveweights at similar degrees of gut fill were used for calculation of feed intake and requirement.

(v) Selection of slaughter groups

Six kids were selected for slaughter at six months of age on a systematic basis (treatment group 6H/M). The kids were ranked in order of increasing liveweight and the first and then every eighth or ninth kid following it was selected for slaughter, ensuring that one kid was chosen from each pen, so that the full range of liveweights was represented. Subsequent slaughter groups were selected from within their appropriate treatment groups using the same system, but two goats were selected from each pen. This system of selection resulted in an increase in the standard deviation of the mean liveweight for each treatment as the trial progressed, but was necessary to ensure that the slaughter groups closely represented the whole treatment group at each slaughter age.

3.2.3 Low level of nutrition

(i) Experimental animals

Due to restrictions imposed by funding, facilities and availability of animals it was not possible to rear the third treatment group, representing the low level of nutrition, at the trial site. A further 24 Texan x New Zealand Angora wethers were retained on the farm of origin for rearing under commercial conditions until required for slaughter. They were reared on a low level of nutrition due to the adverse effects of high feed intake, particularly protein, on fibre quality. Although detailed feeding records were not available for these goats, they served as a useful control group to describe the carcass composition of goats which are reared solely to optimise fibre quality, with no regard for meat yield or quality.

Eighteen yearling Angora wethers, born relatively late in June 1989, were available from the same source and of similar genetic stock. These constituted treatment groups 12L, 18L and 24L.

Since no more wether kids were available from the 1990 kidding of this source, the remaining six kids, treatment group 6L, were obtained from the same farm from the 1991 kidding, since variation due to genotype and management conditions is likely to be greater than that due to year of kidding. The kids in treatment group 6L were born in March 1991.

(ii) Management of low plane goats

The commercially reared goats were run at grass with their dams until they were four to five months of age, when they were weaned onto lamb pellets containing 160g crude protein/kg DM (Lydney and District Farmers, Dean, Glos.). Treatment group 6L was slaughtered off grass immediately after they were shorn at six months of age. Treatment groups 12L, 18L and 24L were housed for their first Winter and fed a proprietary coarse feed containing an estimated 10.5 MJ ME and 176g crude protein/kg DM (Wessex Goat Mix, John Loader Ltd., Fordingbridge, Hants.) with hay, straw or silage as available. They were shorn in December,

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at six months of age, and turned out to grass again the following April at an estimated stocking density of 15 goats per hectare. They were shorn for the second time in June and treatment group 12L was slaughtered. The remaining goats remained outside during their second Winter but were provided with wind/rain shelters. They received no supplementary feeding during this time except for one month after their third shearing in December, when they were housed and fed hay, straw or silage supplemented with minerals. Treatment group 18L was slaughtered immediately after shearing. Treatment group 24L was shorn in June at 24 months of age and slaughtered immediately afterwards. Liveweight gain was not monitored for the commercially reared goats.

Each slaughter group was randomly selected from the main group by the farm staff at the time of slaughter. The goats were generally collected from the farm on a Friday, within two weeks of shearing, and transported 100 kilometres to Seale-Hayne. They were housed indoors and rested over the weekend with free access to barley straw and fresh water. On Monday morning they were weighed and then transported a distance of four kilometres to the local abattoir. They were all slaughtered within one hour of delivery to the abattoir, thus being subjected to the minimum of stress.

3.2.4 Measurement of fleece and fibre characteristics

All of the goats were shorn prior to slaughter. Shearing took place at six months of age and thereafter at six monthly intervals according to current commercial practice. Greasy fleece weights were recorded. Prior to shearing a mid-side fibre sample, approximately 5cm^2, was taken from the left side of each goat for analysis of staple length and fibre diameter. The samples were taken over the last rib, approximately 10cm from the spine, according to the method of Gifford (1989). The use of an Oster electric small animal hand clipper (Oster Professional Products, Wisconsin, U.S.A.) with blade size 40 allowed the samples to be taken at skin level. An equivalent sample was taken from the right side three months after each shearing, to allow more frequent monitoring of fibre characteristics throughout the trial.

Difficulty was experienced in obtaining fleece weights and pre-shearing fibre samples for the

L plane animals since advance warning of shearing could not always be obtained. Consequently, for the majority of the L plane treatment groups only fibre diameter data was collected.

3.2.5 Analysis of fibre samples

Ten staples were randomly selected from every sample and the length of each measured to the nearest 5mm. Snippets of fibre approximately 5mm long were cut from the root end of the ten measured staples, mounted in liquid paraffin (B.P.) on a 76 x 26mm glass microscope slide and covered with a glass cover slide. Fibre diameter was then measured on 100 random snippets using the projection microscope technique (Hutchings and Ryder, 1985).

The slide was mounted on a Gillet and Siebert projection microscope. Using a 120 x 170 mm hand mirror, held at an angle of approximately 10° from horizontal by a retort stand and clamp, the image of the fibres was projected onto a levelled digitizer pad (MacTablet) linked to an Apple Macintosh Classic personal computer. The height of the digitizer pad was adjusted so that the image was magnified x270. Using a Basic program based on the theory of Pythagoras and written specifically for the task, fibre diameter was measured by touching the digitizer stylus onto each outside edge of the fibre image, taking care that the line between the points was as perpendicular to the long axis of the fibre as could be achieved manually.

The system was calibrated with a 1000μm slide graticule (Graticules Ltd., Tonbridge, Kent) and verified with seven standard samples of mohair ranging from 23.1μm to 42.7μm. The standards were tested by the International Mohair Association using both projection microscope and wind tunnel determination. The current system was accurate to within ± 2μm of the standard measurements.

3.2.6 Slaughter procedure

The goats were weighed prior to slaughter using an electronic weigh crate and immediately transported to the abattoir to prevent further intake of feed and water. They were slaughtered

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by captive bolt stunning and exsanguination via the jugular vein within one hour of delivery to the abattoir.

The pelt (fleece and skin, including ears and head cover) was stripped from the carcass and weighed with a spring balance to the nearest 50 grammes. The feet were removed by cutting between the proximal edge of the metacarpus / metatarsus and the distal edge of the carpal / tarsal bones, and weighed on an electronic balance to the nearest gramme. The head was dislocated from the neck at the atlanto occipital joint and removed complete with lungs, trachea, liver, spleen, heart and oesophagus, the whole being termed the pluck. The warm pluck was weighed with a spring balance to the nearest 50 grammes.

The gastro-intestinal tract from rumen to rectum was removed, complete with contents, and returned to the trial site. The full tract was weighed with a spring balance to the nearest 50 grammes and the contents of the rumen, reticulum, omasum, abomasum, caecum and colon were emptied. The empty tract was washed, squeezed to remove excess moisture and re-weighed to obtain gut fill by difference. Omental fat was stripped from the stomachs as completely as possible and weighed. The intestine was placed in a sealed container and chilled at 2°C for two to four hours to facilitate removal of the mesenteric and intestinal fat, which was also weighed.

The warm, dressed carcass was weighed on a spring balance to the nearest 50 grammes and then chilled for 24 hours at the abattoir.

Empty body weight (EBW) was determined by subtracting gut fill from liveweight.
Killing out percentage was calculated as 100 x (warm carcass weight / empty body weight).

3.2.7 Jointing procedure

The carcasses were collected from the abattoir, double wrapped in plastic bags, and put into cold storage at 2°C for no longer than 48 hours before jointing. Standard M.L.C. measurements were taken on the freely hanging whole carcass as follows:-

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1. The weight of the cold carcass.

2. The F measurement - taken, using a steel tape measure, as the distance between the most distal point on the medial edge of the central and fourth tarsal bones to the most caudal point on the median line between the legs (Figure 3.1).

3. The T measurement - taken, using a steel tape measure, as the distance between the most distal anterior edge of the central and fourth tarsal bones and the proximal edge of the tibial tuberosity (this point being found by inserting a skewer into the joint between the tibia and the femur - point A).

4. The greatest width of the chest, measured with a 30cm calliper gauge.

5. The circumference of the buttocks, using a steel tape measure held horizontally around the buttocks of the freely hanging carcass at the level of the proximal edge of the patellas.

All linear measurements were taken to the nearest five millimetres.

The carcass was sawn through the centre of the vertebral column. Pieces of spinal cord, large pieces of aorta and diaphragm were removed and discarded, and the tail was removed down to the level of the posterior edge of the third caudal vertebra. The kidney and perinephric and retroperitoneal fat (kidney knob and channel fat, KKCF) were removed from each side and their weights recorded separately. Any thoracic fat was removed and weighed. The weight of the right side was recorded and the unjointed side was then folded, securely wrapped in plastic bags and frozen.
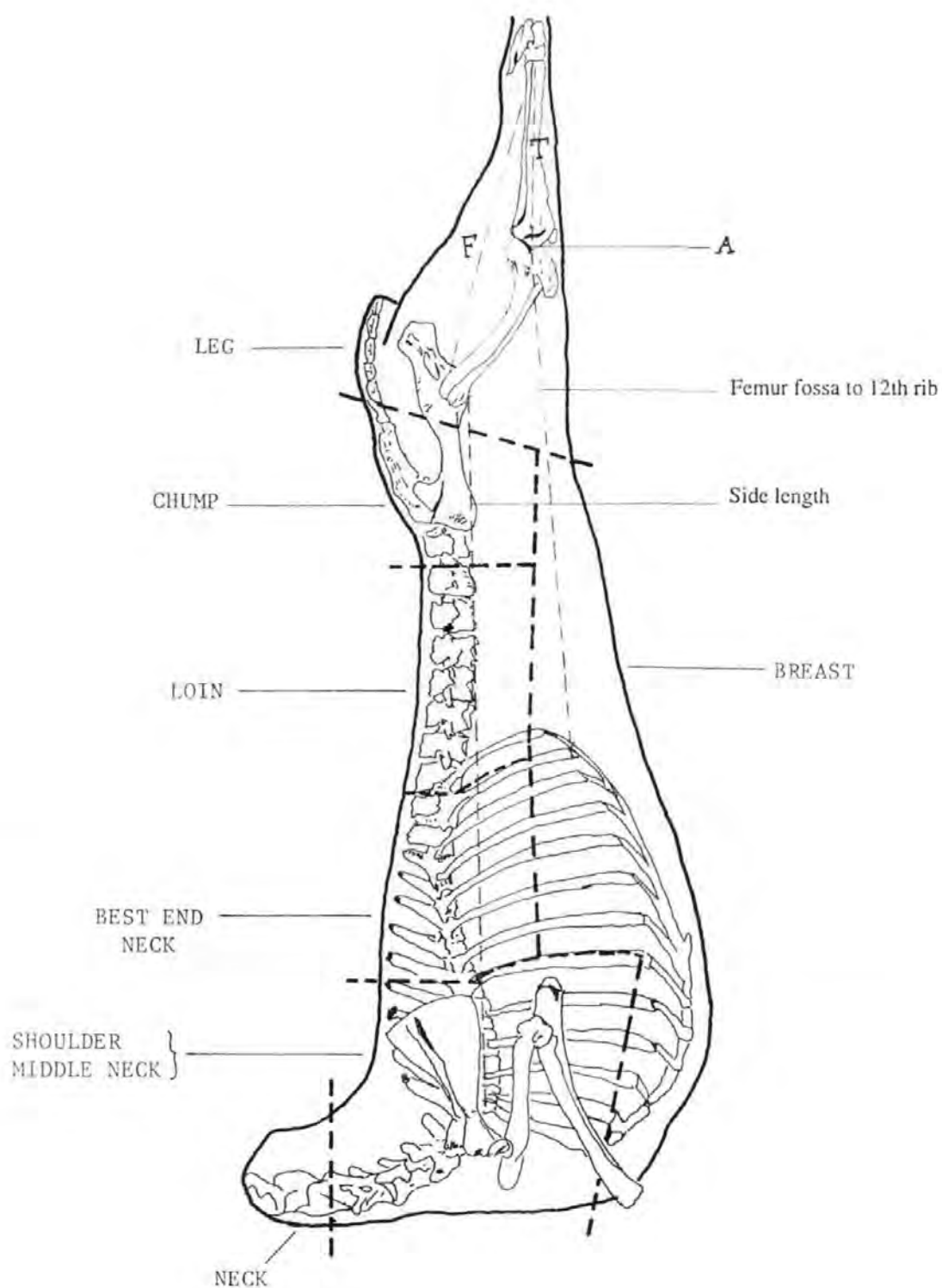
Figure 3.1

Standardised commercial lamb joints and linear carcass measurements
used in Trial 1 and Trial 2

The weight of the left side was recorded and the following measurements were taken on the freely hanging side to the nearest five millimetres:-

1.   The maximum depth of the side using a 30cm calliper gauge.

2.   The length of the side from the anterior edge of the pubic symphysis to the dorsal anterior corner of the first thoracic vertebra, using a steel tape measure.

3.   The length from the femur fossa to the 12th rib. This was determined by inserting a skewer through the carcass on the anterior edge of the 12th rib at the most ventral point of attachment with the diaphragm and recording the distance between this and point A with a steel tape measure.

The left side was then split into commercial joints according to the procedures described by Cuthbertson, Harrington and Smith (1972) and adopted by the M.L.C., to yield the following joints: leg, chump, loin, breast, middle neck and shoulder, best end of neck and scrag end of neck (Figure 3.1). The scrag was weighed on an electronic balance to the nearest 0.1 gramme and then discarded, since separation of the head and neck at the abattoir was not performed accurately enough to merit dissection of such a small joint. The remaining joints were weighed, individually sealed in airtight plastic bags and frozen until dissection could be performed.

3.2.8 Carcass dissection

Due to the expense and labour incurred in dissecting whole carcasses, a complete dissection was conducted on one side of the carcass only. This is a satisfactory method of arriving at the composition of the whole carcass, provided the side weights are not significantly different (Callow, 1944), the carcasses are evenly split along the spinal column and an adequate number of animals is available (Carroll and O'Carroll, 1964). In this study the side weights from each carcass were the same ± 0.1kg, with the exception of one goat in group 12H which was unevenly split. In this case both sides of the carcass were dissected.

The joints were removed from frozen storage and thawed in their sealed bags for

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approximately 12 hours at room temperature. Each joint was then re-weighed and dissected with a butchers knife into subcutaneous and intermuscular fat, lean and bone according to standard M.L.C. techniques. The weight of each component was recorded. Easily dissectible glands, major blood vessels, ligaments and tendons were recorded separately as waste. The thawed joints were held in the cold store at approximately 2°C until dissection and the joint and its dissected components were covered with damp cloths throughout dissection, in order to minimize loss of moisture. As a result of using these measures weight loss during dissection was restricted to 2% or less.

In addition to the determination of gross joint composition, the following measurements were taken:-

1. At the rib end of the loin joint the subcutaneous fat thickness was measured over the widest part of the eye muscle and 6cm from the mid-line using a 10cm calliper gauge.

2. The outline of the eye muscle at the above position was traced onto grease-proof paper using a soft leaded pencil and the area determined with an electronic planimeter (Delta-T Devices Ltd., Burwell, Cambridge).

    The greatest width (A) and the greatest depth (B) of the eye muscle was also measured to the nearest millimetre and the ratio A/B x 100 was calculated (Pálsson and Vergés, 1952).

3. The *M. Longissimus dorsi* was removed intact from the loin and best end of neck and its weight was recorded for each.

3.2.9 Statistical analysis

One-way and two-way analysis of variance, paired t-tests, linear regressions and covariance analysis were undertaken as refered to in Section 3.3 using Minitab version 6.1. It should be noted that the use of repeated results in Section 3.3.11 may have influenced the significance of the results. The repeated fibre sampling of the same groups of goats at different ages rather than the random sampling of different goats of various ages probably resulted in a lower total variance which would have increased the probability of obtaining a significant age effect.

3.3 Results and discussion

3.3.1 Growth curve of the British Angora wether goat from four to 24 months of age

Individual fed liveweights were recorded for the **H** and **M** plane goats each week from four to 24 months of age. The weights were corrected for fleece cover by extrapolating backwards from shorn fleece weight to zero fleece cover following the previous shearing. Up to six months of age fleece-free liveweight was estimated by extrapolating backwards to zero fleece cover at birth. Fleece weight was assumed to be negligible at birth, consisting mainly of primary fibres which are shed prior to the first shear at six months of age (Westhuysen *et al.*, 1985, Tiffany-Castiglioni, 1986).

Paired means of fleece corrected, fed liveweight were plotted against age in days to produce a growth curve for each plane of nutrition (Figures 3.2a and b). The 95% confidence limits showed that the standard deviation increased as the number of goats fell due to sequential slaughter. The confidence limits were wider for the **H** than for the **M** plane goats due to the greater variation in feed intake and gut fill of the goats fed *ad libitum*.

Weekly liveweights were not available for the **L** plane goats. For comparison with the other treatments their mean fleece-free liveweight at slaughter was plotted against approximate age in days (Figure 3.2c). The 95% confidence limits were narrower for the **L** treatment because the same number of goats was represented at each age.

For each treatment a simple linear regression was fitted to the points. The slope of the regression line represented the mean growth rate of the goats throughout the trial. As a result of the treatment imposed on them the mean growth rate of the **L** plane goats was 0.47 that of the **M** plane goats and 0.27 that of the **H** plane goats. The mean growth rate of the **M** plane goats was 0.58 that of the **H** plane goats (Figure 3.2d).

Regression lines were also derived using only the data from treatment groups 24H and 24M.

These regression lines were compared by covariance analysis with those incorporating all available liveweights for the **H** and **M** plane goats respectively (Figures 3.2a and b) and were not found to be significantly different (P > 0.05). This confirmed that the growth curves produced using all available data accurately represented the curves of one continuous group of goats, and were not affected by the gradual decrease in goat numbers with age.

a) High plane, y = 10.21 + 0.0605x, R = 0.97

..... 95% confidence limits
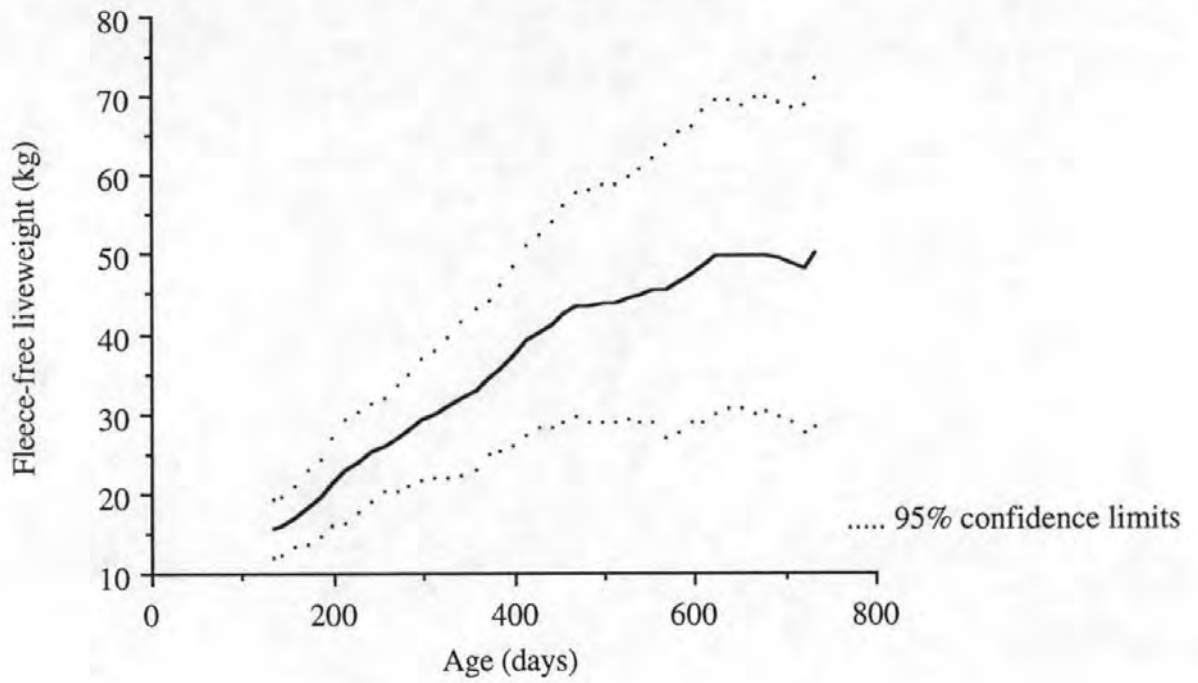
b) Medium plane, y = 13.78 + 0.0348x, R = 0.97

.....95% confidence limits
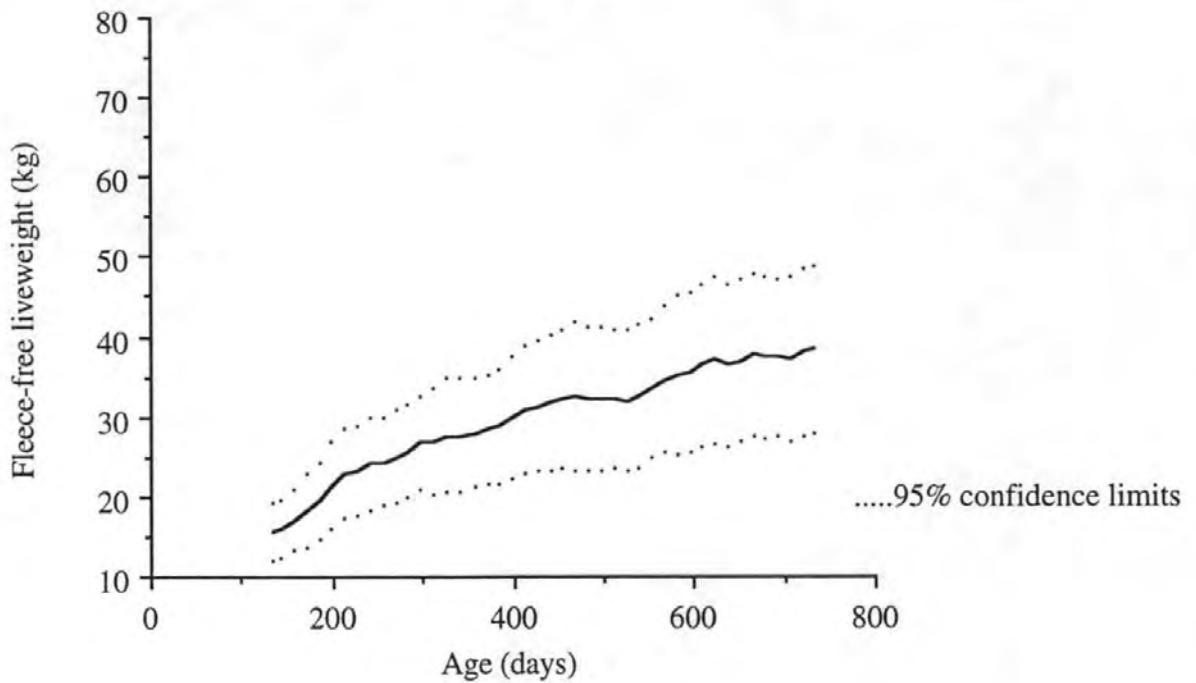
Figure 3.2

Liveweight gain of British Angora wether goats reared on a high, medium or low
plane of nutrition from six to 24 months of age

c) Low plane, y = 19.31 + 0.0162x, R = 0.93
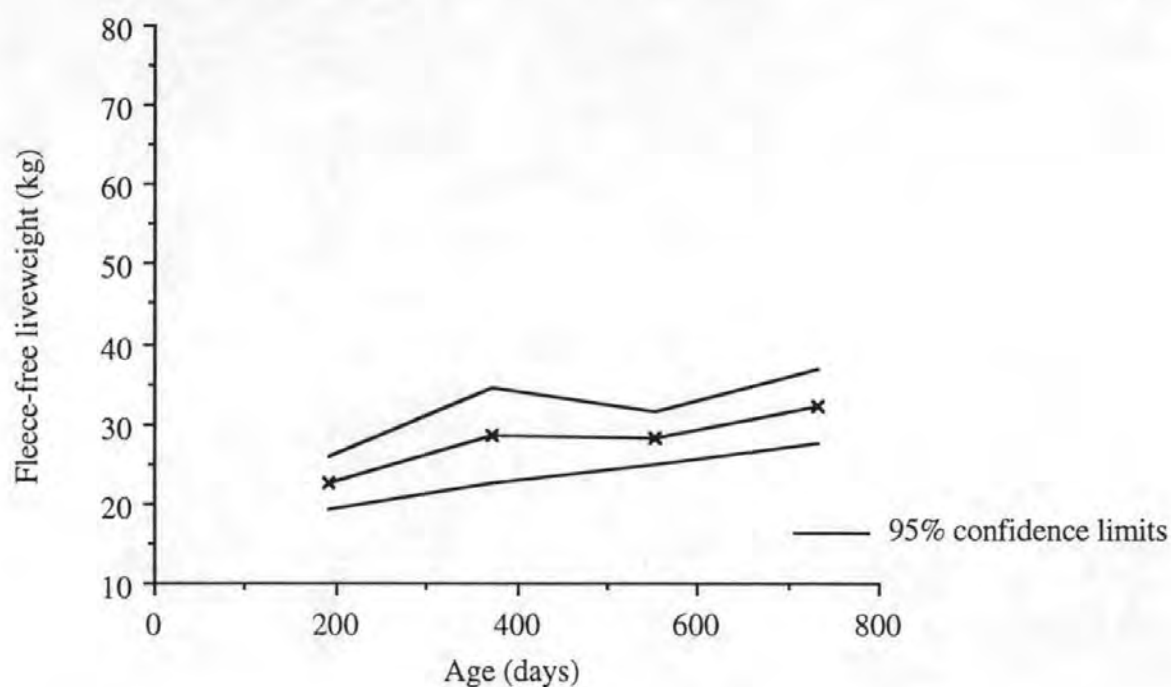
d) All planes
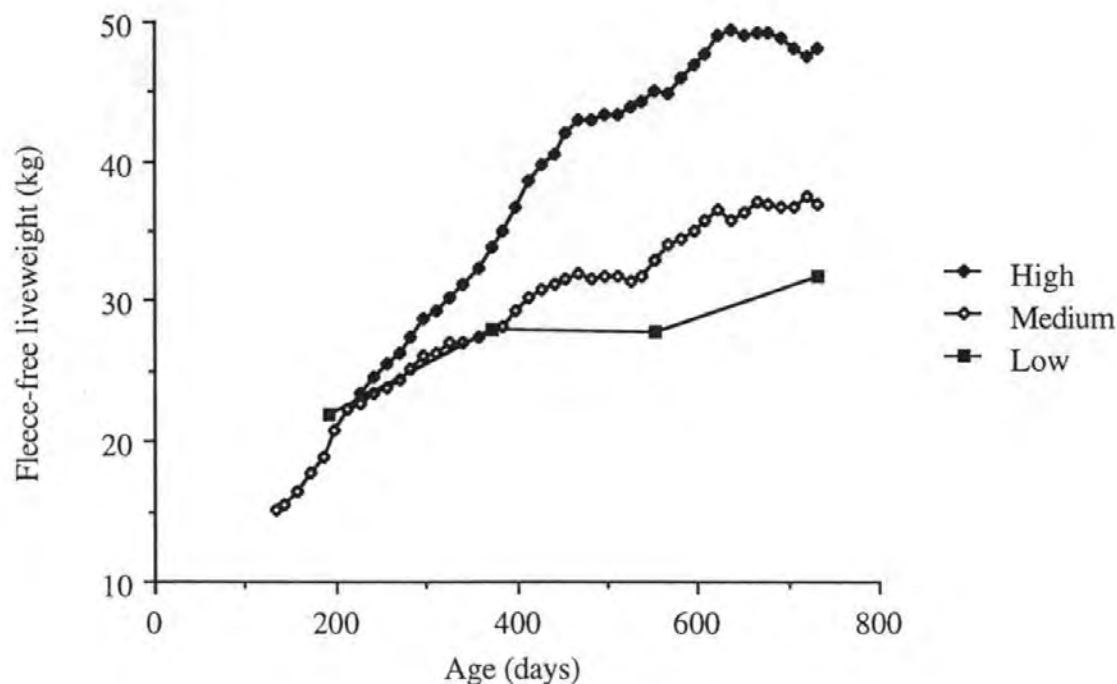
Figure 3.2 (continued)

Liveweight gain of British Angora wether goats reared on a high, medium or low plane of nutrition from six to 24 months of age

3.3.2 Voluntary feed intake of British Angora wether goats reared from six to 24 months of age on a single pelleted feed

The mean daily voluntary feed intake per pen of **H** plane goats and the corresponding rationed intake of the **M** plane goats was recorded from six to 24 months of age. For each pen of goats the mean weekly dry matter intake per kg of fleece corrected metabolic body size was calculated and plotted against time (Figure 3.3).

There was a clear repeating pattern of peaks and troughs in feed intake throughout the trial. The voluntary feed intake of the **H** plane goats increased immediately after each shearing to peak values of 90 to $120g/kg^{0.75}$ and then gradually declined to approximately 60 to $70g/kg^{0.75}$ prior to the next shearing. This repeating trend suggested that as the depth of fleece increased the feed requirement of the goats decreased. The insulation afforded by the fleece may have caused an increase in body temperature which inhibited feed intake. When the fleece was removed feed intake increased again (Forbes, 1986). The dramatic effect of fleece insulation on the feed requirement of these animals indicated that it is difficult to estimate their maintenance requirement under conditions of varying fleece cover. The maintenance requirement represented in Figure 3.3 was that recommended by the NRC (1981). It was derived from pooled means of experimental data performed mainly on dairy goats which suggested that it should more accurately apply to the fleece free Angora goat than to the goat in full fleece.

A complicating factor in this scenario was that almost immediately after each shearing two goats were removed from each pen for slaughter. It was possible that the removal of some of the competition for trough space resulted in a change in the dominance hierarchy within each pen, allowing a previously inhibited goat greater access to the feed.

The mean dry matter intake per unit of metabolic body size per six month period from shearing/slaughter to shearing/slaughter was calculated for Period II (6 to 12 months), Period III (12 to 18 months) and Period IV (18 to 24 months) for the two planes of nutrition (Table 3.2).

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Within each period the mean dry matter intake/kg$^{0.75}$ of the **H** plane goats was significantly greater than that of the **M** plane goats. There were no significant differences in mean dry matter intake between pens within each plane of nutrition and within each period of feeding.

There was a significant decrease in the total mean voluntary dry matter intake/kg$^{0.75}$ of the **H** plane goats between successive periods and consequently a similar pattern for the **M** plane goats (Figure 3.3). The mean voluntary dry matter intake of the **H** plane goats was 84g/kg$^{0.75}$ for period II and 78g/kg$^{0.75}$ for period III. During periods II and III the mean dry matter intake of the **M** plane goats was approximately 80% of that of the **H** plane goats (Table 3.2).

During period IV the voluntary dry matter intake of the **H** plane goats fell significantly to a mean value of 56g/kg$^{0.75}$. The large decrease was due to a rapid decline in feed intake during the last three months of the trial (Figure 3.3). At this stage the **M** plane goats were put onto a constant maintenance ration in preference to feeding a below maintenance quantity. Consequently the mean dry matter intake/kg$^{0.75}$ of the **M** plane goats exceeded that of the **H** plane goats for the last three months of the trial. For the whole period their mean feed intake was 92% of *ad lib* which was still significantly lower than that of the **H** plane goats (P < 0.05).

There were two possible explanations for the downwards trend in voluntary feed intake;

a) The same diet was fed to the goats for a total period of 20 months. It was possible that boredom with the diet resulted in a gradual decline in feed intake.

b) The slaughtered **H** plane goats had sizeable internal fat deposits, particularly surrounding the gastro-intestinal tract and kidneys, which increased with age (Table 3.5). It was possible that this fat deposition inhibited feed intake, either through physical restriction of the gut cavity, or via some lipostatic mechanism (Forbes, 1986).
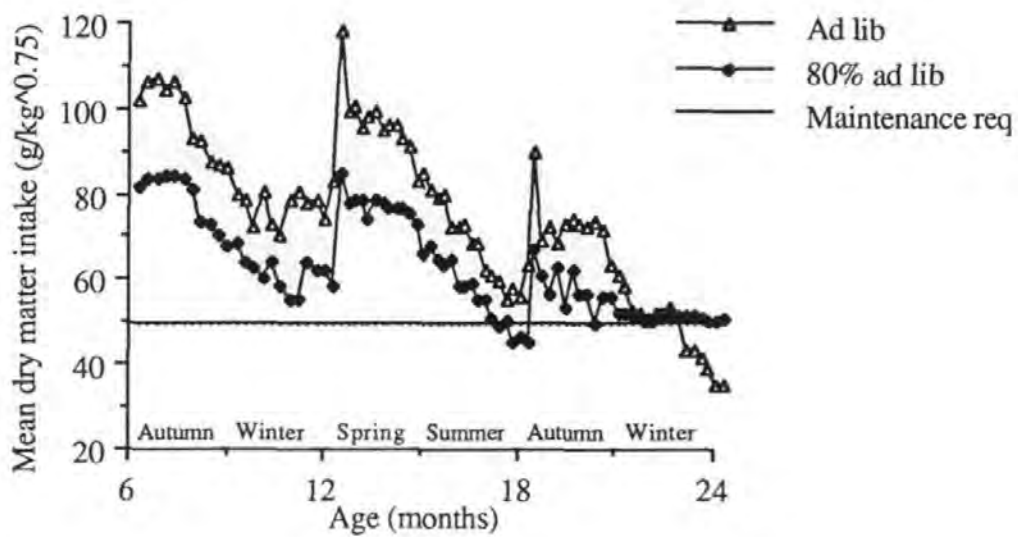
Figure 3.3

Mean daily voluntary dry matter intake (g/kg liveweight$^{0.75}$) of Angora wether goats reared from six to 24 months of age on a single pelleted feed

	Pen number										
	High plane				Medium plane						
Period	1	4	5	Mean	2	3	6	Mean	s.e.	Sig.	% of High
II	84.78	79.77	88.72	84.42a	67.11	68.23	65.89	67.08a	0.985	***	79
III	80.04	74.72	79.51	78.09b	62.23	65.32	60.63	62.73b	1.150	***	80
IV	52.72	58.28	56.85	55.95c	49.36	53.05	52.24	51.55c	0.895	*	92
Mean	72.51	70.92	75.03	72.51	59.57	62.20	59.59	60.25	0.744	***	83

Means within columns with different superscripts are significantly different (P < 0.001)

Table 3.2

Mean dry matter intake (g/kg liveweight$^{0.75}$) of Angora wether goats reared from six to 24 months of age on a high or medium plane of nutrition

3.3.3 Statistical comparison of slaughtered and remaining treatment group liveweights and of dissected and non-dissected carcass side weights

(i) Comparison of slaughtered and remaining treatment group liveweights

One way analysis of variance was conducted on the fleece free liveweights of the H and M treatment groups prior to each slaughter to ensure that no bias existed between treatments at the start of the trial, and to ensure that the slaughtered goats were a good representation of all goats on the same level of nutrition at each age (Table 3.3). Liveweights were not available for the L plane goats for a similar comparison.

Age (months)	6H/M	12H	18H	24H	s.e.	Sig.	12M	18M	24M	s.e.	Sig.
				Treatment group							
6	21.1	22.0	19.2	20.0			21.7	19.8	20.4	0.45	NS
12		33.6	32.0	32.9	1.38	NS	28.3	26.3	27.0	0.89	NS
18			46.2	43.8	2.56	NS		32.1	32.5	1.34	NS

Table 3.3

Mean fleece-free liveweight (kg) of slaughtered and remaining Angora wether goats reared on a high or medium plane of nutrition from six to 24 months of age

The mean liveweight did not differ significantly between treatment groups at six months of age. This confirmed that there was no bias towards either plane of nutrition at the start of the trial and that the slaughtered group, 6H/M, was a good representation of all remaining treatment groups at that age. Similarly there were no significant differences between treatment groups at each age within each plane of nutrition, which confirmed that at each age sampled the slaughtered goats were a good representation of the remaining goats.

(ii) Comparison of carcass side weights

A paired t-test was conducted on the weights of the right and left sides of carcasses in each treatment group in order to determine whether dissection of a single side would fairly represent the composition of the whole carcass. There were significant differences between the weights of right and left sides in some treatment groups (Table 3.4).

Treatment group	Left side	Right side	s.e.	Significance
6H/M	3.99	3.97	0.046	NS
12H	7.83	7.83	0.052	NS
18H	11.29	10.95	0.078	* *
24H	11.37	11.57	0.089	NS
12M	6.07	6.05	0.101	NS
18M	6.95	6.71	0.126	NS
24M	8.74	8.80	0.119	NS
6L	4.54	4.55	0.038	NS
12L	5.20	5.40	0.066	*
18L	5.08	5.24	0.052	*
24L	6.36	6.64	0.118	NS

Table 3.4

Mean weight of left and right cold side (kg) of Angora wether goats reared from six to 24 months of age on a high, medium or low plane of nutrition

Treatment group 18H had significantly heavier left sides than right sides ($P < 0.01$). Treatment groups 12L and 18L had significantly heavier right sides than left sides ($P < 0.05$). These differences suggested that some or all of the carcasses in these groups may have been inaccurately split through the vertebral column, resulting in the half carcass dissection being unrepresentative of whole carcass composition. However a non-significant result in the above analysis did not prove that the two sides of each carcass were identical in composition. When the carcass dissections were performed several joints from the left (dissected) sides were obviously unevenly split. In these instances the corresponding joint from the right side was also dissected and the mean tissue weight from the two joints was taken to represent that

joint.

Some of the treatment groups identified in Table 3.4 as having unequal side weights were not observed to have unevenly split joints upon dissection. Since time was limited it was not feasible to dissect both sides of such carcasses. In these cases it was concluded that the differences between side weights were due to differences intrinsic to the animal material. The difference in weight between the right and left sides varied from 0 to 700g in the worst case, and averaged 134g overall. When proportioned between the three main tissues and the waste fraction these differences were not large enough to significantly affect the representation of the whole carcass composition by half carcass dissection.

3.3.4 The effect of age and plane of nutrition on the body and carcass composition of the British Angora wether goat

Two way analysis of variance was conducted on the body and carcass composition data to determine the effect of age (A), plane of nutrition (N) and their interaction (I) on the growth and development of the British Angora wether goat. Data from treatment group 6H/M was entered into the analysis twice since it represented both the **H** and **M** plane goats at six months of age. The least significant range was calculated at the 5% level of significance to determine the significance of the differences between each treatment group.

There was a significant effect of age, plane of nutrition and their interaction on liveweight, empty body weight (EBW), killing-out percentage and the weights of all body and carcass components at slaughter (Table 3.5). Values increased from six to 24 months of age and were greater for the **H** than the **L** plane of nutrition with the **M** plane intermediate (Figures 3.4 and 3.5).

(i) High plane

There was a significant increase in EBW and in the weights of most body components of the **H** plane goats up to 18 months of age. There were two exceptions. The lungs showed no significant increase at any age with a mean weight of 227g, and the combined liver and spleen increased significantly from 460.7g in group 6H/M to 662.5g in group 12H but showed no significant increase thereafter (Table 3.5). This indicated the early developing nature of these vital organs.

Between 18 and 24 months of age there was no significant increase in EBW, the weight of the feet, the pelt or any of the essential organs (Table 3.5, Figure 3.4a). This signified the earlier maturing nature of the heart, kidneys and gastro-intestinal tract (GIT) and the external offal relative to the carcass and non-carcass fat depots.

Although the vital organs showed little increase in weight after 18 months of age the

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increases up to that age seemed disproportionately large compared with the complete lack of growth of the lungs. It would have been more consistent for the other organs to cease to grow at a younger age (compare with other studies). It was possible that the increases in weight of the heart, liver and spleen and kidneys up to 18 months of age was due to fat accretion, or glycogen in the liver, rather than to the growth of the organ tissue itself.

WCW increased non-significantly between 18 and 24 months of age from 25.1kg to 27.4kg. Similarly omental fat increased non-significantly from 2.77kg in group 18H to 3.29kg in group 24H (Table 3.5). These increases did not reach statistical significance because they were not as great as the differences between the younger age groups due to the overall decline in growth rate of the older goats (Figure 3.2a). While the fat-free carcass (lean plus bone) did not increase in weight beyond 18 months of age, the weights of intermuscular fat (IMF), subcutaneous fat (SCF) and kidney knob and channel fat (KKCF) increased non-significantly up to 24 months of age (Figure 3.5a) and the weight of thoracic fat increased significantly between 18 and 24 months of age from 13.0g to 36.3g (Table 3.5). The increase in WCW beyond 18 months of age was therefore due to carcass fat development and not to the growth of lean or bone.

These observations suggested that on the high plane of nutrition the fat-free body had reached its maximum weight of approximately 30kg (by difference) by 18 months of age. Any subsequent increase in EBW would be due solely to increases in carcass and omental fat. The lack of any increase in weight of mesenteric and visceral fat between 18 and 24 months of age (Table 3.5) indicated that these depots were relatively early maturing compared with omental fat, KKCF, IMF and SCF and as such had reached their maximum weight by 18 months of age in the H plane goats.

The goats in group 24H were on average genetically smaller than those in group 18H. This was indicated by the lower mean weights of the feet, head and vital organs of the former (Table 3.5, Figure 3.4a) and also by their lower mean liveweight at 18 months of age (43.8 v 46.2kg, Table 3.3). Consequently there was no increase in EBW between 18 and 24 months of age despite the increase in total fat content of the empty body between those ages (Table

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3.5).

The apparent increase in bone mass from 1.417kg in group 18H to 1.950kg in group 24H (Table 3.5, Figure 3.5a) was due to differences in the dissection technique used in that treatment group compared with that used in the dissection of earlier carcasses, rather than to an actual increase in bone mass with age.

(ii) Medium plane

The weights of most body and carcass components increased with each age increment up to 24 months of age in the M plane goats (Figures 3.4b and 3.5b) indicating their relatively later maturity compared with those reared on the H plane of nutrition. There were few significant differences between age groups because the increases were small compared with the much larger differences in the H plane goats (Table 3.5).

The lungs were the exception to the overall pattern. They showed no differences between any age groups and had a mean weight of 200g. This again emphasised their early maturity relative to other body components even on a lower plane of nutrition (Table 3.5). The continued increase in weight of the other vital organs up to 24 months of age may again have been due to the accretion of stored nutrients rather than to growth of the organ tissues, since there was no increase in the weight of the fat-free GIT beyond 18 months of age (Table 3.5, Figure 3.4b). Other studies have suggested that the heart, the liver and spleen and the kidneys should be earlier maturing than the GIT and therefore should not have increased in weight to greater ages than the latter (Pálsson and Vergés, 1952; Wilson, 1958b, 1960).

The weights of the external offal components also increased up to 24 months of age, with the exception of the pelt which decreased slightly from 3.3kg in group 18M to 2.8kg in group 24M (Table 3.5, Figure 3.4b). This was attributed to the fact that group 24M was shorn on the day of slaughter and therefore did not carry two weeks of fleece growth as did the younger age groups.

WCW increased with every age increase due to the growth of all carcass components up to 24 months of age (Table 3.5, Figure 3.5b). Carcass bone appeared to increase rapidly from 1.248kg in group 18M to 1.757kg in group 24M but this was again attributed to differences in dissection technique rather than to a sudden surge in bone growth. The weights of all non-carcass fat depots increased up to 24 months of age (Table 3.5).

(iii) Low plane

The patterns of growth and development of the L plane goats were complicated by a cessation of growth and weight loss of certain body components between 12 and 18 months of age. This was caused by sub-maintenance feed intakes on the commercial system of production (Materials and methods). There were few significant differences between age groups due to the relatively small changes compared with the H plane goats.

EBW increased from 18.9kg to 23.2kg between six and 12 months of age, remained constant up to 18 months of age and then increased to 27.8kg at 24 months of age (Table 3.5, Figure 3.4c). The vital organs demonstrated their high priority for available nutrients by continuing to increase in weight up to 24 months of age (Table 3.5), with the exception of the lungs which again did not grow between six and 18 months of age. Inexplicably the lungs increased in weight significantly between 18 and 24 months of age, reaching a mean weight of 290g which exceeded that of group 24H. This was attributed to error in the collection and weighing of the organs since no other explanation was available. The fat-free GIT increased in weight from 1.87kg at six months to 2.3kg at 24 months of age (Table 3.5). Since the data was missing for groups 12L and 18L it was impossible to say whether the tract continued to grow for the whole of that period or whether it had reached its mature weight earlier. The external offal continued to grow unchecked up to 24 months of age, indicating their high priority for available nutrients (Table 3.5).

WCW increased from 9.7kg at six months to 11.4kg at 12 months of age (Table 3.5, Figure 3.4c). It then decreased to 10.8kg at 18 months before increasing again to 14.3kg in group 24L. While carcass bone continued to increase throughout the trial from 1.095kg in group 6L

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to 1.515kg in group 24L (Table 3.5) all other carcass components lost weight between six and 18 months of age before regaining some of it at 24 months (Figure 3.5c). KKCF and SCF began to lose weight at 12 months of age, suggesting that as late maturing tissues they were mobilised as soon as the nutrient supply became limiting to the development of the earlier maturing components such as lean and bone. Both fat depots regained some weight at 24 months of age (Table 3.5). IMF did not decrease until 18 months of age, indicating its earlier maturing nature and therefore its greater priority over available nutrients compared with KKCF and SCF. Similarly carcass lean was not affected until 18 months of age (Table 3.5, Figure 3.5c). These results were consistent with those of Robinson (1948) who showed that the pattern of weight loss in mature ewes was the exact reverse of weight gain, with the most rapid loss in carcass fat, slow loss in carcass lean and no effect on the skeleton.

The non-carcass fat depots also showed signs of early mobilisation in response to nutrient insufficiency. Omental fat decreased from 606g in group 6L to 363g in group 18L before increasing again to 479g in group 24L (Table 3.5). Due to missing data in groups 12L and 18L for mesenteric and visceral fat it was impossible to say how soon these depots were mobilised.

The failure of the L plane goats to increase in EBW between 12 and 18 months of age was due to mobilisation and consequently weight loss of both carcass and non-carcass fat and some lean, in order to fuel the growth of the vital organs, external offal and skeleton which continued to grow throughout the trial.

These results suggested that the growth of the British Angora wether goat followed the same pattern of development as that described by Sir John Hammond and his co-workers in the pig and the sheep, namely early maturity of the organs and external offal, followed by the fat-free carcass with later maturity of carcass and non-carcass fat depots (Pálsson, 1955).

| | Treatment group | | | | | | | | | | | | Significance of effect of | | |
| | High | | | | Medium | | | Low | | | | | | | |
	6H/M	12H	18H	24H	12M	18M	24M	6L	12L	18L	24L	s.e.	A	N	I
Liveweight (kg)	21.3a	33.7b	46.5c	45.7c	28.6ab	32.3b	36.2bc	21.2a	27.3ab	27.1ab	31.0ab	0.62	***	***	**
EBW (kg)	18.4a	31.4cd	43.9e	43.8e	25.3abcd	28.6bcd	33.5d	18.9ab	23.2abc	23.2abc	27.8abcd	0.59	***	***	***
WCW (kg)	8.7a	17.4cd	25.1de	27.4e	13.5abcd	15.3bcd	19.2d	9.7ab	11.4abc	10.8ab	14.3abcd	0.37	***	***	***
Killing out %	47.1a	55.3cd	57.0d	62.6e	53.6cd	53.2cd	56.9d	51.3bc	49.1ab	46.6a	51.3bc	0.24	***	***	***
Pelt (kg)	2.5ab	3.6bcd	4.6d	4.2cd	3.1abc	3.3abcd	2.8ab	2.5ab	3.3abcd	2.1a	3.4bcd	0.08	***	***	***
GIT (kg)†	2.8a	4.5b	6.9d	6.1cd	3.8ab	4.3ab	4.5bc	2.9a	3.2ab	3.6ab	3.3ab	0.10	***	***	***
Pluck (kg)†	1.8a	2.6cd	3.6g	3.4g	2.3bc	2.8de	3.2efg	2.1ab	2.4bcd	2.9def	3.3fg	0.03	***	***	***
Feet (g)	506a	773bcde	923e	905de	676abc	730bcd	793cde	601ab	679abc	685abc	870de	11.0	***	**	**

Means in the same row with the same superscript are not significantly different (P < 0.05);

† Includes associated fat

Table 3.5

Effect of age and plane of nutrition on the mean weights of major body and carcass components of Angora wether goats (means of six goats)

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| | Treatment group | | | | | | | | | | | | | Significance of effect of | | |
| | High | | | | Medium | | | Low | | | | | | | | |
	6H/M[1]	12H	18H	24H[2]	12M	18M	24M	6L	12L[1]	18L[1]	24L	s.e.	A	N	I
Heart (g)	80.2a	112.3abc	157.7d	148.1cd	88.8a	116.7abc	144.8cd	91.0a	103.3ab	129.3bcd	157.7d	2.31	***	*	NS
Lungs (g)	223.3bcd	207.5abc	261.5cd	216.5acd	201.2abc	168.3ab	207.5abc	138.8a	199.3abc	167.8ab	290.5d	4.80	**	*	***
Liver & spleen (g)	460.7ab	662.5cde	822.0e	694.7de	495.2abc	507.2abc	604.9bcd	382.3a	443.0ab	493.0abc	667.7cde	10.9	***	***	***
Kidney (g)	35.5ab	52.8cd	61.6d	52.8cd	43.0abc	43.2abc	46.0abc	32.0a	34.0ab	37.7ab	47.0bc	0.86	***	***	**
GIT (kg)	2.4	2.9	1.8	2.2	2.5	2.4	1.9				2.3	0.01	**	NS	NS
Head (kg)	0.97a	1.35bc	1.88d	1.97de	1.28b	1.88d	1.95de	1.47bc	1.59c	2.12de	2.19e	0.02	***	***	NS
Visceral fat (kg)	0.118	0.257	0.249	0.077	0.124	0.128	0.055				0.039	0.04	**	NS	NS
Omental fat (kg)	0.493ab	1.500c	2.771d	3.294d	0.984abc	1.212abc	1.487bc	0.606abc	0.454a	0.363a	0.479a	0.06	***	***	***
Mesenteric fat (kg)	0.629	1.150	1.023	0.567	0.579	0.681	0.387				0.471	0.05	**	NS	NS
KKCF (kg)	0.389ab	1.188c	2.204d	2.621d	0.727abc	0.931bc	1.276c	0.469ab	0.393ab	0.229a	0.272a	0.04	***	***	***
Thoracic fat (g)†	0.0a	6.5a	13.0ab	36.3c	6.6ab	10.2ab	22.0bc	4.1a	13.0ab	0.0a	0.0a	0.97	***	***	***

Means in the same row with the same superscript are not significantly different ($P > 0.05$);

† Left side only;

1 Visceral and mesenteric fat not removed;

2 Visceral fat, heart, lungs, liver and head (n = 5)

Table 3.5 (continued)

| | Treatment group | | | | | | | | | | | | Significance of effect of | | |
| | High | | | | Medium | | | Low | | | | | | | |
	6H/M	12H	18H	24H	12M	18M	24M	6L	12L	18L	24L	s.e.	A	N	I
Dissected side (kg)	3.784a	7.366bc	10.123de	11.113e	5.682abc	6.343abc	8.36cd	4.144a	5.010ab	4.760ab	6.123abc	0.16	***	***	***
Bone (kg)	0.864a	1.201abc	1.417bcd	1.950e	1.024a	1.248abc	1.757de	1.095ab	1.136abc	1.177abc	1.515cd	0.02	***	*	**
Lean (kg)	1.893a	3.761dfg	4.805g	4.446fg	3.025bde	3.003bde	3.881efg	2.015ab	2.690abd	2.456abc	3.482cdf	0. 06	***	***	***
Total fat (kg)	0.988a	2.350abc	3.861cd	4.694d	1.586ab	2.066ab	2.690bc	1.021a	1.151ab	1.078ab	1.089ab	0.10	***	***	***
IMF (kg)	0.392ab	0.986bcd	1.389de	1.699e	0.677abc	0.799acd	1.048cd	0.350a	0.512abc	0.473abc	0.413ab	0.06	***	***	***
SCF (kg)	0.596a	1.364a	2.472bc	2.995c	0.910a	1.267a	1.642ab	0.672a	0.639a	0.605a	0.676a	0.04	***	***	***

Means in the same row with the same superscript are not significantly different (P > 0.05)

Table 3.5 (continued)

a) High plane

b) Medium plane

c) Low plane

WCW
Pelt
Fat free pluck
Fat free GIT
Feet
Remainder
Non-carcass fat

Figure 3.4

Empty body composition of Angora wether goats reared from six to 24 months of age
on a high, medium or low plane of nutrition

a) High plane

b) Medium plane
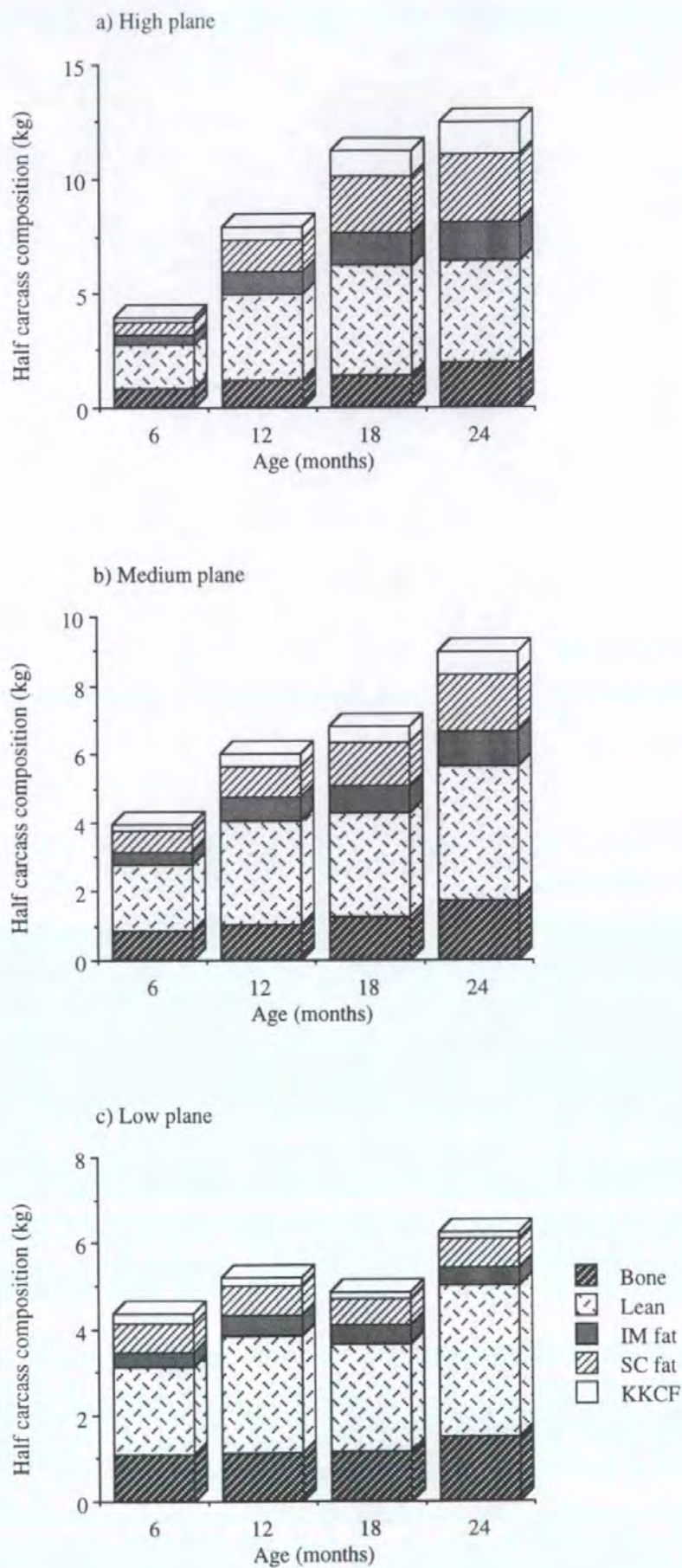
c) Low plane

Figure 3.5

Half carcass composition of Angora wether goats reared from six to 24 months of age
on a high, medium or low plane of nutrition

The effect of increasing the plane of nutrition from **L** to **H** on the earlier maturing body components such as the pelt, feet and GIT was greater in the younger treatment groups, up to 18 months of age, than in the more mature animals (Figure 3.6b, c and e). The effect on the later maturing non-carcass fat and warm carcass was greatest in the oldest animals (Figures 3.6f and 3.7a). In the very early maturing pluck there was little effect of increasing plane of nutrition at any age (Figure 3.6d).

Similarly the effect of increasing the plane of nutrition on the warm carcass was small in the very early maturing bone at all ages (Figure 3.7b). The effect on lean was greatest at 18 months of age and decreased at 24 months of age (Figure 3.7c) while the effect on the late maturing carcass fat depots was greatest in the most mature treatment groups (Figures 3.7d, e and f).
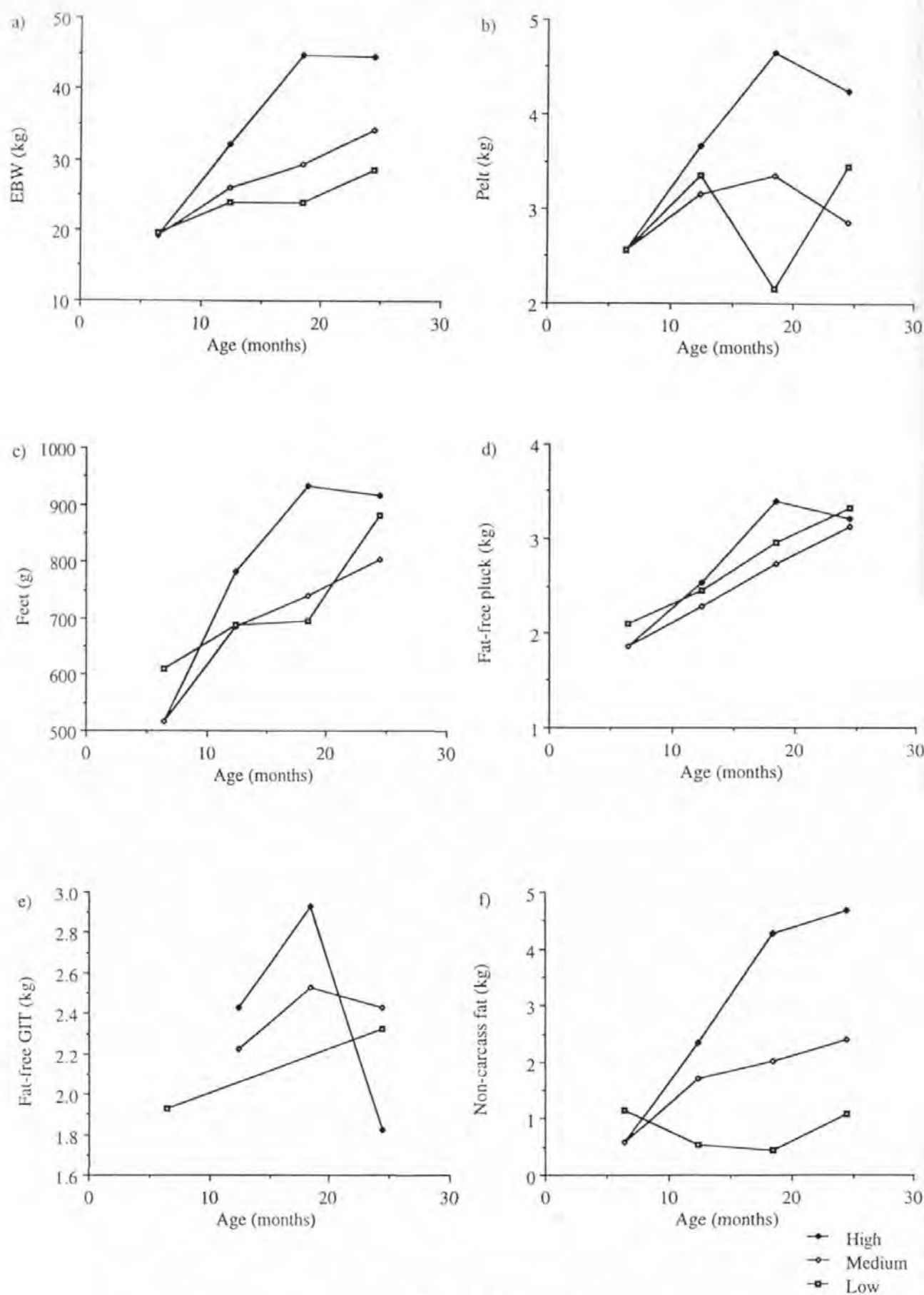
Figure 3.6

The effect of plane of nutrition from six to 24 months of age on the weight of body
components of Angora wether goats
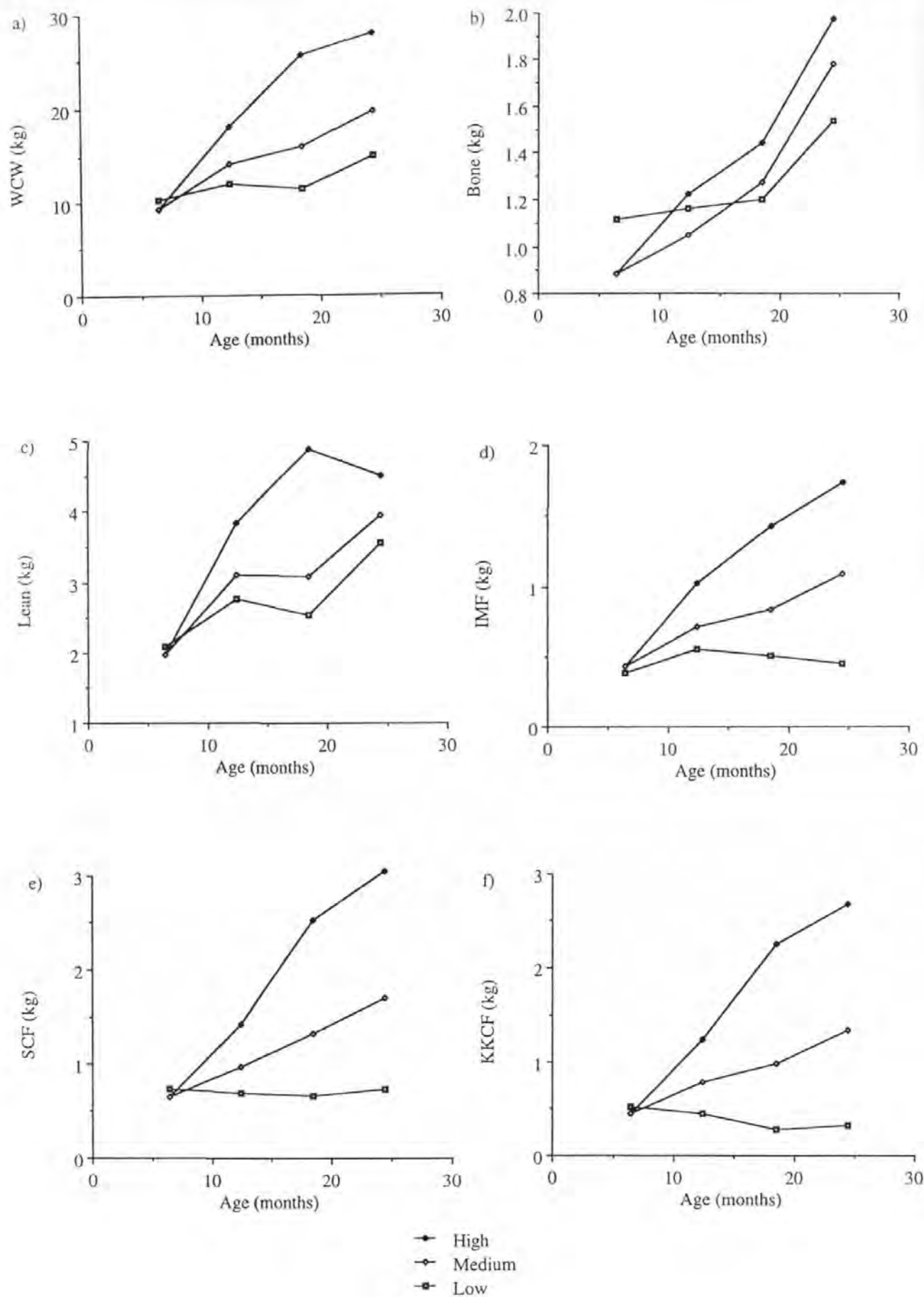
Figure 3.7

The effect of plane of nutrition from six to 24 months of age on the weight of carcass components of Angora wether goats

3.3.5 The effect of age and plane of nutrition on the body conformation of the British Angora wether goat

Body conformation was measured by means of linear measurements of the cold carcass and by means of the weights and proportions of the commercial joints.

(i) Linear measurements

All of the linear measurements increased significantly with increasing age (Table 3.6, Figure 3.8). They also increased significantly with increasing plane of nutrition with the exception of the total leg length, F, which had a mean value of 240mm (Figure 3.8a). The F measurement can be affected by the accumulation of fat in the crutch of the carcass (Colomer-Rocher and Kirton, 1989) and this may have masked the leg length of the fatter goats. The lower leg length, T, increased significantly from 148mm in the L plane goats to 157mm in the H plane goats (Figure 3.8b).

(a) High plane

In the H plane goats there was a clear pattern of development of carcass conformation with age (Figure 3.9a, Table 3.7) which was consistent with that identified by McMeekan in the pig (1940a, b and c) and by Pálsson and Vergés in the sheep (1952). At 24 months of age the measurements identified by these workers as being later developing i.e. chest width and side depth, had increased proportionately more over values at six months of age (96.0% and 34.7% respectively) than the earlier developing leg and side length measurements. The T measurement had increased by only 17.0%, the F measurement by only 21.5% and side length by 23.7%. These measurements were essentially measures of skeletal development and indicated that in the young animal growth of the skeleton occurred mainly by increased leg length, first lower and then upper leg, and by increased carcass length. In the more mature animal the skeleton became deeper and wider.

The circumference of the buttocks reflected lean and fat development as well as skeletal

growth and consequently was one of the later developing parameters, showing a large increase of 37.2% at 24 months of age over the value at six months.

(b) Medium plane

Carcass conformation in the **M** plane goats showed the same pattern of development with age as that of the **H** plane goats (Figure 3.9b) but the proportional increases in each measurement over values at six months of age were lower (Table 3.7).

(c) Low plane

In the **L** plane goats differences in the order of development of the linear measurements indicated the less advanced stage of maturity of the carcass at each age compared with the **H** and **M** plane goats (Figure 3.9c). Lower leg length, T, was still the earliest maturing parameter, increasing by only 9.3% at 24 months of age over its value at six months. There was little difference between the proportional increases of the remaining linear measurements by 24 months of age (Table 3.7). Side depth increased the most, by 20.3%, while increases in chest width and the circumference of the buttocks were inhibited by the low plane of nutrition and had increased proportionately less than any other measurement, 9.4% and 11.8% respectively, except for T. The decrease in the circumference of the buttocks between 12 and 18 months of age, and in chest width between 18 and 24 months of age indicated that these measurements were influenced by lean and fat development, both of which were adversely affected by the poor feed intakes of the **L** plane goats throughout the trial (Figure 3.8e and f).

Increasing the plane of nutrition from **L** to **H** had a greater effect on the earlier maturing parameters i.e. leg length, side length and length from femur fossa to 12th rib, in the younger age groups (Figures 3.8b, c and d respectively). At 24 months of age the differences between the treatment groups became less as each parameter reached maturity in the **H** plane goats but continued to increase in the **L** plane goats.

Conversely there was a greater effect of increasing the plane of nutrition on the later maturing parameters in the oldest animals. The circumference of the buttocks and chest width continued to increase in the **H** plane goats but remained relatively undeveloped in the **L** plane goats (Figures 3.8e and f respectively).

| | Treatment group | | | | | | | | | | | | Significance of effect of | | |
| | High | | | | Medium | | | Low | | | | | | | |
	6H/M	12H	18H	24H	12M	18M	24M	6L	12L	18L	24L	s.e.	A	N	I
CCW	8.4a	17.0cd	24.7ef	27.2f	13.0abc	14.8bcd	19.2de	9.5ab	11.1abc	10.5ab	13.5acd	0. 36	***	***	**
F	223	242	238	271	237	236	252	221	237	245	256	2.20	***	NS	NS
T	141	157	166	165	151	161	160	140	145	154	153	1.06	***	**	NS
Circumference of buttocks	436a	528cd	585e	598e	504bcd	513cd	558de	450ab	476abc	474abc	503bc	3.26	***	***	***
Chest width	125	200	230	245	178	194	214	149		171	163	?	?	NS	NS
Side depth	225	272	289	303	253	263	272	231	257	263	278	2.15	***	**	NS
Side length	518	583	621	641	560	578	622	523	558	550	602	3.30	***	***	NS
Femur fossa to 12th rib	363a	504de	543ef	555f	467bcd	494cde	518ef	434b	444bc	460bcd	509def	3.02	***	***	***

Means in the same row with the same superscript are not significantly different (P > 0.05)

Table 3.6

Effect of age and plane of nutrition on cold carcass weight (kg) and carcass linear measurements (mm) of Angora wether goats (means of six goats)
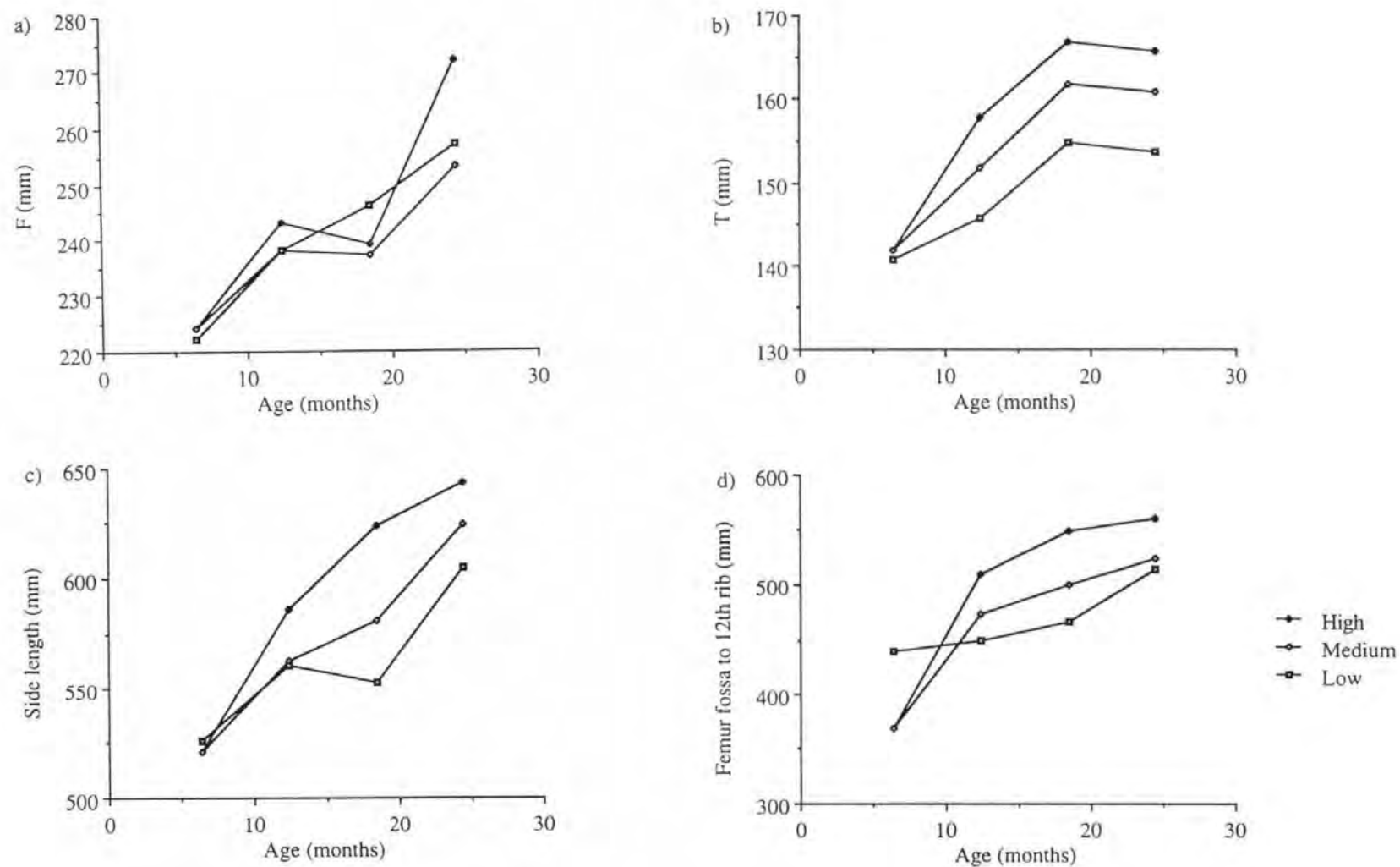
Figure 3.8

The effect of plane of nutrition from six to 24 months of age on the linear carcass measurements of Angora wether goats
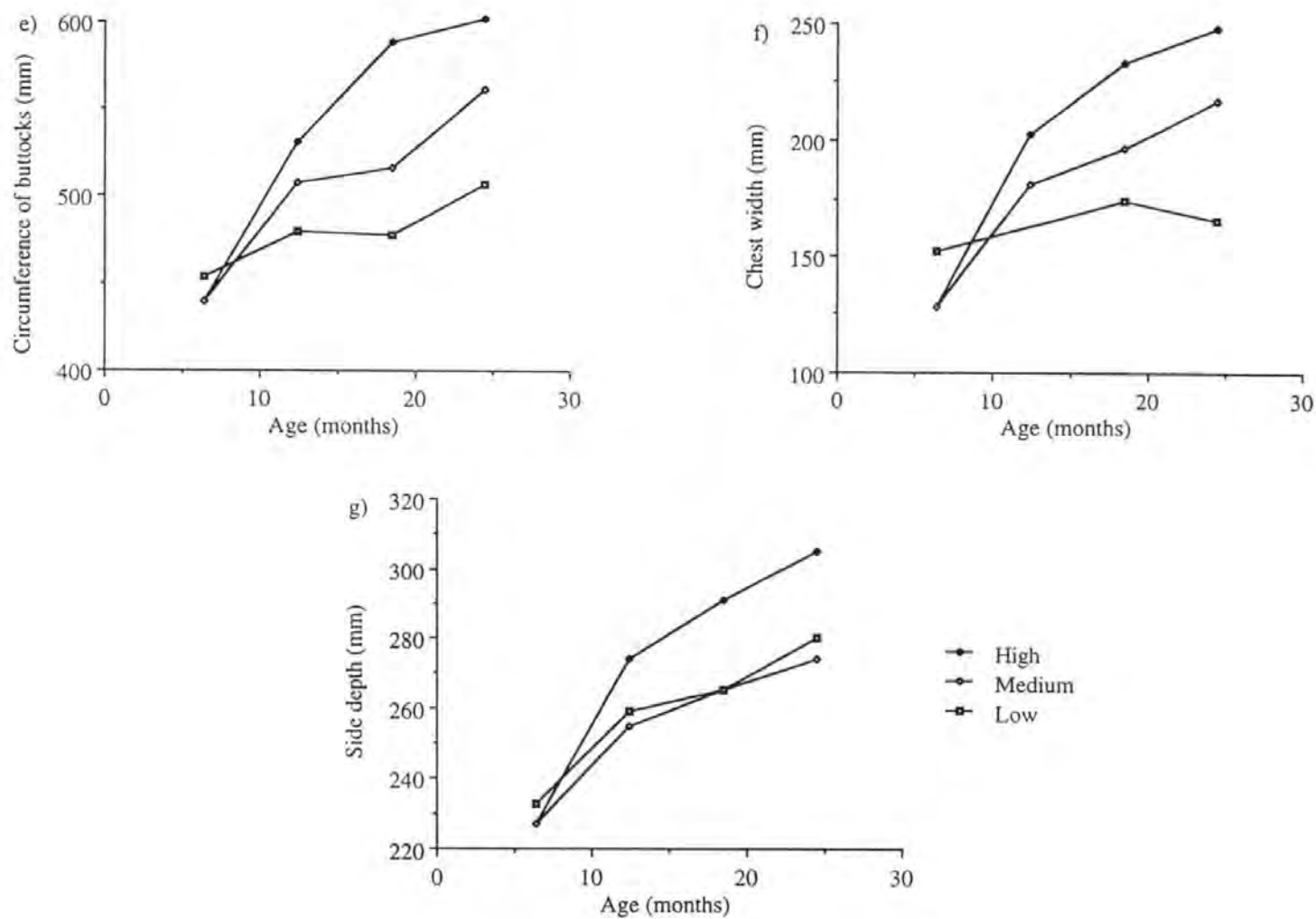
Figure 3.8 (continued)

The effect of plane of nutrition from six to 24 months of age on the linear carcass measurements of Angora wether goats

| | Treatment group | | | | | | | | |
| | High | | | Medium | | | Low | | |
	12H	18H	24H	12M	18M	24M	12L	18L	24L
F	8.5	6.7	21.5	6.3	5.8	13.0	7.2	10.9	15.8
T	11.3	17.7	17.0	7.1	14.2	13.5	3.6	10.0	9.3
Circumference of buttocks	21.1	34.2	37.2	15.6	17.7	28.0	5.8	5.3	11.8
Chest width	60.0	84.0	96.0	42.4	55.2	71.2		14.8	9.4
Side depth	20.9	28.4	34.7	12.4	16.9	20.9	11.3	13.9	20.3
Side length	12.5	19.9	23.7	8.1	11.6	20.1	6.7	5.2	15.1
Femur fossa to 12th rib	38.8	49.6	52.9	28.7	36.1	42.7	2.3	6.0	17.3

Table 3.7

Effect of age and plane of nutrition on carcass linear measurements (mm) of Angora wether goats - percentage increase over value at six months (means of six goats)

a) High plane

b) Medium plane

c) Low plane

Legend:
- ⊸ T
- ✦ F
- ⊟ Side length
- ■ Side depth
- ⊶ Circumference of buttocks
- ▲ Femur fossa - 12th rib
- ＋ Chest width
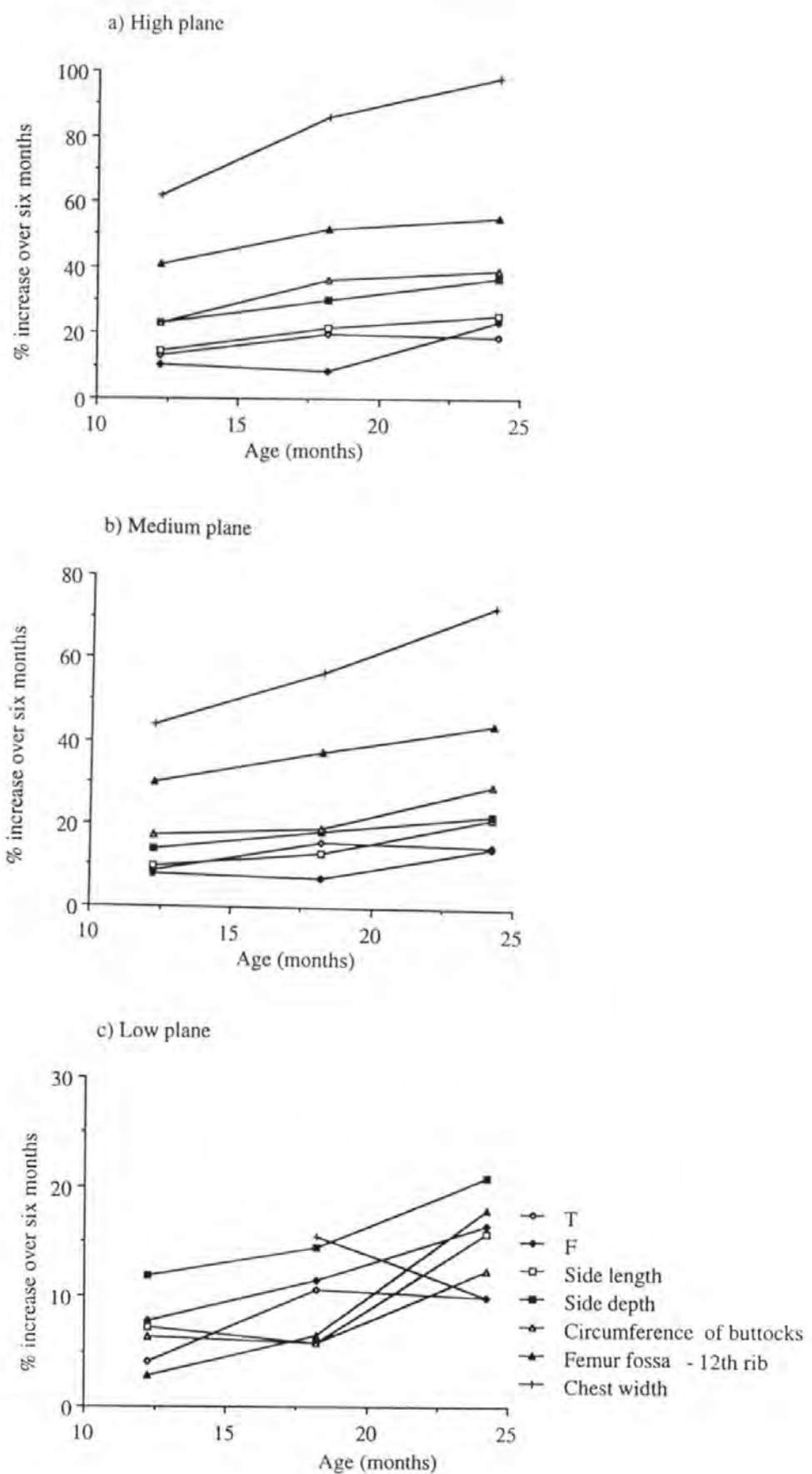
Figure 3.9

The effect of age on the linear carcass measurements of Angora wether goats reared
on a high, medium or low plane of nutrition

(ii) Commercial joints

The weights of all of the commercial joints increased significantly with increasing age and plane of nutrition with the exception of the neck which was not significantly affected by plane of nutrition (Table 3.8, Figure 3.10). This was in part due to inaccuracies in the separation of the neck from the head in treatment group 6H/M, but also reflected the early maturing nature of this joint. The weight of the neck did not differ significantly between treatment groups at 12 months of age and had an average value of 0.247kg at that age (Figure 3.10g).

(a) High plane

The weights of all of the commercial joints, except the neck, increased significantly up to 18 months of age but also increased non-significantly up to 24 months of age in the H plane goats (Table 3.8, Figure 3.10).

At 24 months of age the leg and the shoulder had increased proportionately the least over their value at six months of age (164.4% and 163.6% respectively) while the best end and the loin had increased proportionately the most (272.4% and 261.6% respectively) with the breast and chump intermediate (226.0% and 207.9% respectively) (Table 3.9, Figure 3.11a). This confirmed the existence of a centripetal pattern of growth in the Angora goat, as proposed for other domestic species by Hammond (1955). Consequently the leg, shoulder and neck tended to decrease as proportions of total side weight while the loin, chump, best end and breast tended to increase up to 24 months of age (Table 3.10, Figure 3.12).

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| | Treatment group | | | | | | | | | | | | Significance of effect of | | |
| | High | | | | Medium | | | Low | | | | | | | |
	6H/M	12H	18H	24H	12M	18M	24M	6L	12L	18L	24L	s.e.	A	N	I
Leg	0.897a	1.711cd	2.295e	2.372e	1.396bc	1.507bcd	1.917de	1.103ab	1.285abc	1.362abc	1.620cd	0.03	***	***	**
Chump	0.342a	0.631bc	0.965d	1.053d	0.498ab	0.561abc	0.805cd	0.353a	0.447ab	0.355a	0.518ab	0.02	***	***	***
Loin	0.393a	0.937bcd	1.161de	1.421e	0.587abc	0.725acd	1.004cde	0.409a	0.539ab	0.494a	0.599abc	0.03	***	***	**
Best end	0.279a	0.637bcd	0.954de	1.039e	0.452abc	0.564abc	0.763cde	0.335ab	0.396ab	0.364ab	0.444abc	0.02	***	***	***
Breast	0.420ab	0.838bc	1.362d	1.369d	0.687abc	0.667abc	0.903c	0.371a	0.463ab	0.464ab	0.631abc	0.03	***	***	***
Shoulder	1.515a	2.728cd	3.723e	3.993e	2.143abc	2.405acd	3.110de	1.616ab	1.966abc	1.879abc	2.424bcd	0.05	***	***	***
Neck	0.042a	0.264bcd	0.325d	0.324cd	0.258bcd	0.261bcd	0.315cd	0.188b	0.220bc	0.192b	0.288bcd	0.01	***	NS	***

Means in the same row with the same superscript are not significantly different (P > 0.05)

Table 3.8

Effect of age and plane of nutrition on the weight of commercial carcass joints (kg) of Angora wether goats (means of six goats)
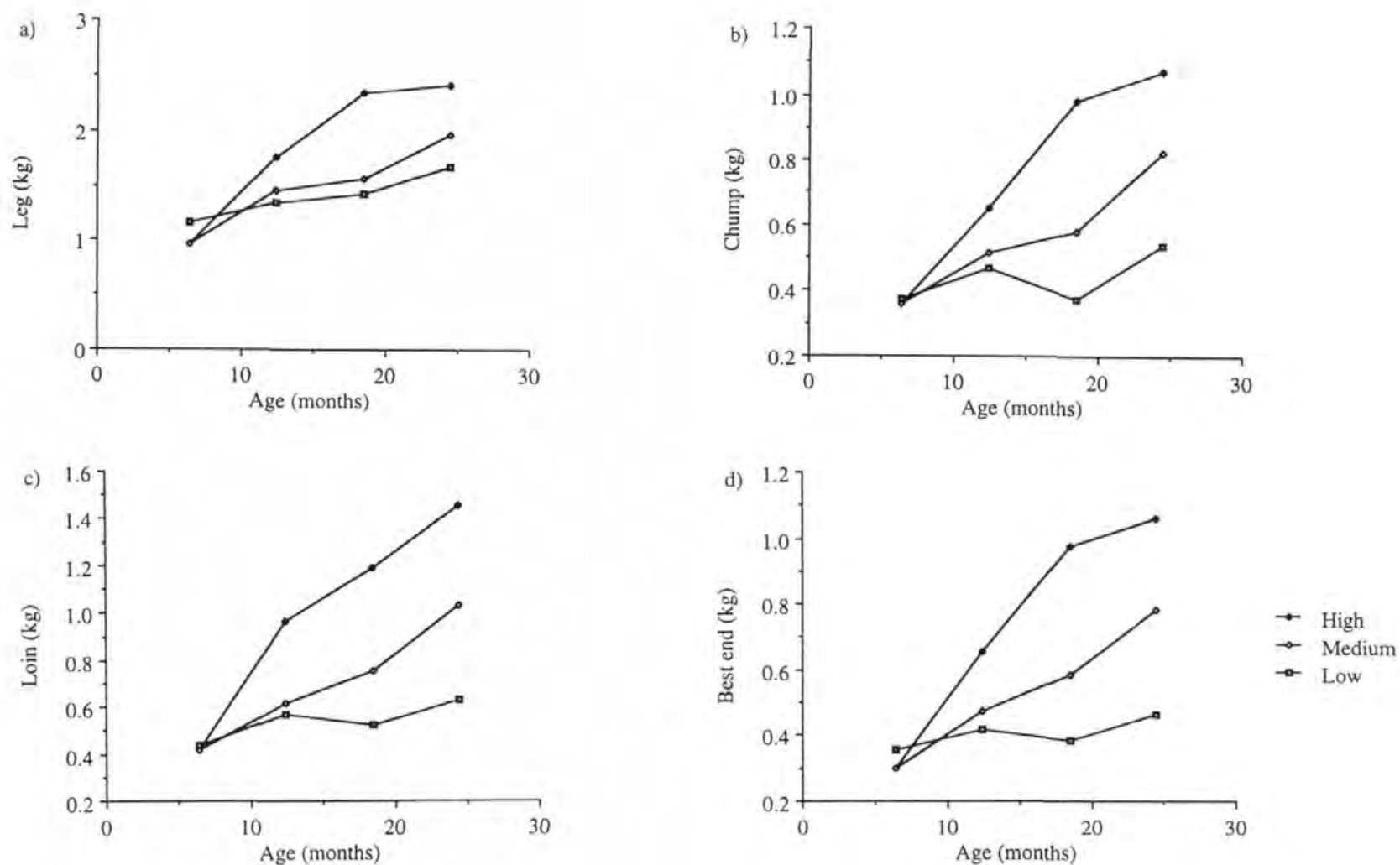
Figure 3.10

The effect of plane of nutrition from six to 24 months of age on the weight of commercial carcass joints of Angora wether goats
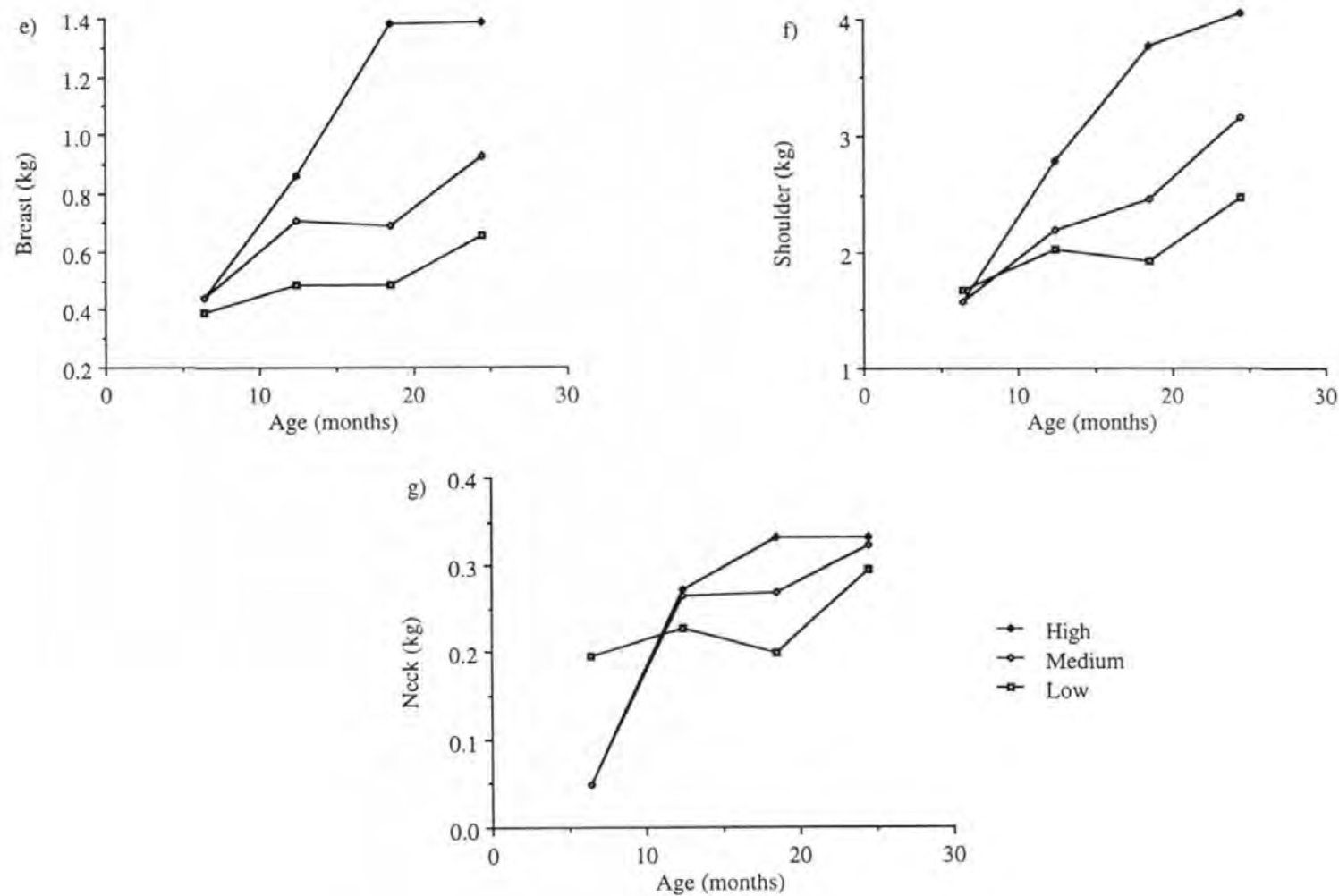
Figure 3.10 (continued)

The effect of plane of nutrition from six to 24 months of age on the weight of commercial carcass joints of Angora wether goats

| | Treatment group | | | | | | | | |
| | High | | | Medium | | | Low | | |
	12H	18H	24H	12M	18M	24M	12L	18L	24L
Leg	90.7	155.9	164.4	55.6	68.0	113.7	16.5	23.5	46.9
Chump	84.5	182.2	207.9	45.6	64.0	135.4	26.6	0.6	46.7
Loin	138.4	195.4	261.6	49.4	84.5	155.5	31.8	20.8	46.5
Best end	128.3	241.9	272.4	62.0	102.2	173.5	18.2	8.7	32.5
Breast	99.5	224.3	226.0	63.6	58.8	115.0	24.8	25.1	70.1
Shoulder	80.1	145.7	163.6	41.5	58.7	105.3	21.7	16.3	50.0

Table 3.9

Effect of age and plane of nutrition on the weight of commercial carcass joints of Angora wether goats - expressed as percentage increase in weight over value at six months of age (means of six goats)
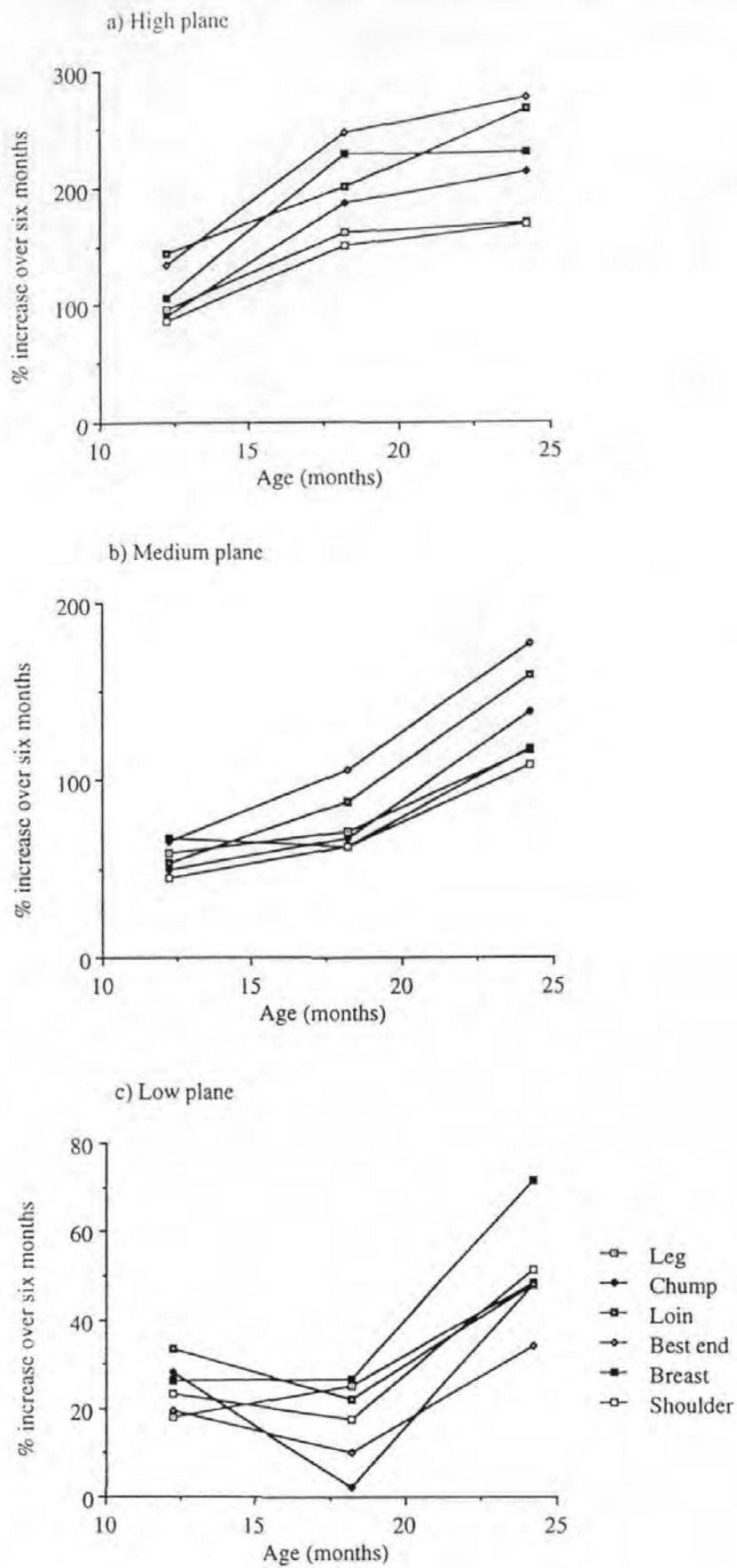
Figure 3.11

The effect of age on the percentage increase in weight of commercial carcass joints of Angora wether goats reared on a high, medium or low plane of nutrition

	High					Medium				Low				
	6H/M	12H	18H	24H	Mean	12M	18M	24M	Mean	6L	12L	18L	24L	Mean
Leg	22.5	21.9	20.3	20.9	21.4	23.0	21.7	21.9	22.3	24.3	24.9	26.8	25.5	25.4
Chump	8.6	8.1	8.6	9.3	8.6	8.2	8.1	9.2	8.5	7.8	8.7	7.0	8.1	7.9
Loin	9.9	12.0	10.3	12.5	11.2	9.7	10.5	11.5	10.4	9.0	10.4	9.7	9.4	9.7
Best end	7.0	8.1	8.5	9.1	8.2	7.5	8.1	8.7	7.8	7.4	7.7	7.2	7.0	7.3
Breast	10.5	10.7	12.1	12.0	11.3	11.3	9.6	10.3	10.5	8.2	9.0	9.1	9.9	9.1
Shoulder	38.0	34.8	33.0	35.1	35.2	35.3	34.7	35.6	35.9	35.6	38.0	37.0	38.1	37.2
Neck	1.1	3.4	2.9	2.9	2.5	4.5	3.8	3.6	3.2	4.1	4.3	3.8	4.5	4.2

Treatment group

Table 3.10

Effect of age and plane of nutrition on the weight of commercial carcass joints of Angora wether goats - expressed as percentage of cold side weight (means of six goats)
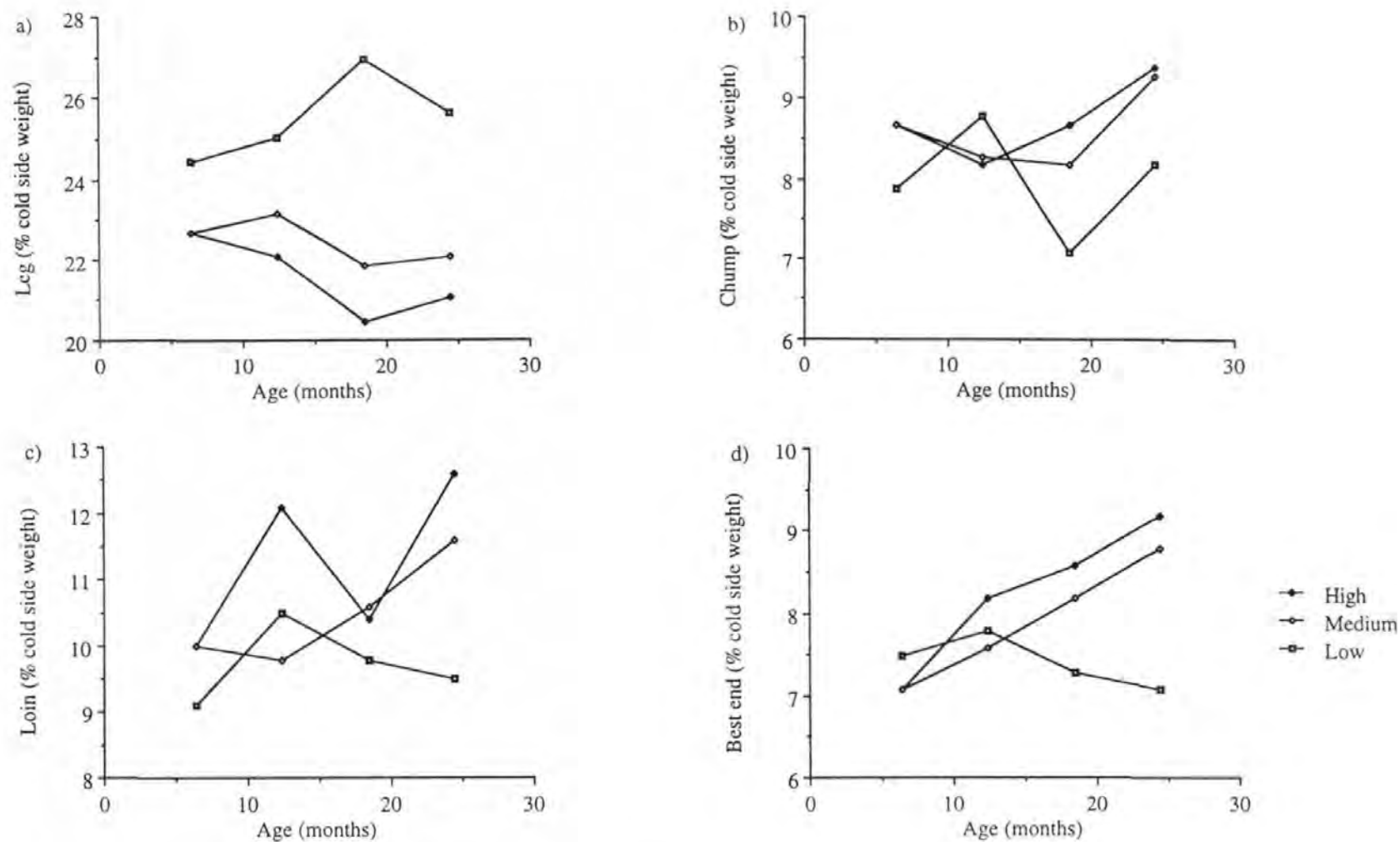
Figure 3.12

The effect of plane of nutrition from six to 24 months of age on the weight of commercial carcass joints of Angora wether goats - expressed as a proportion of cold side weight
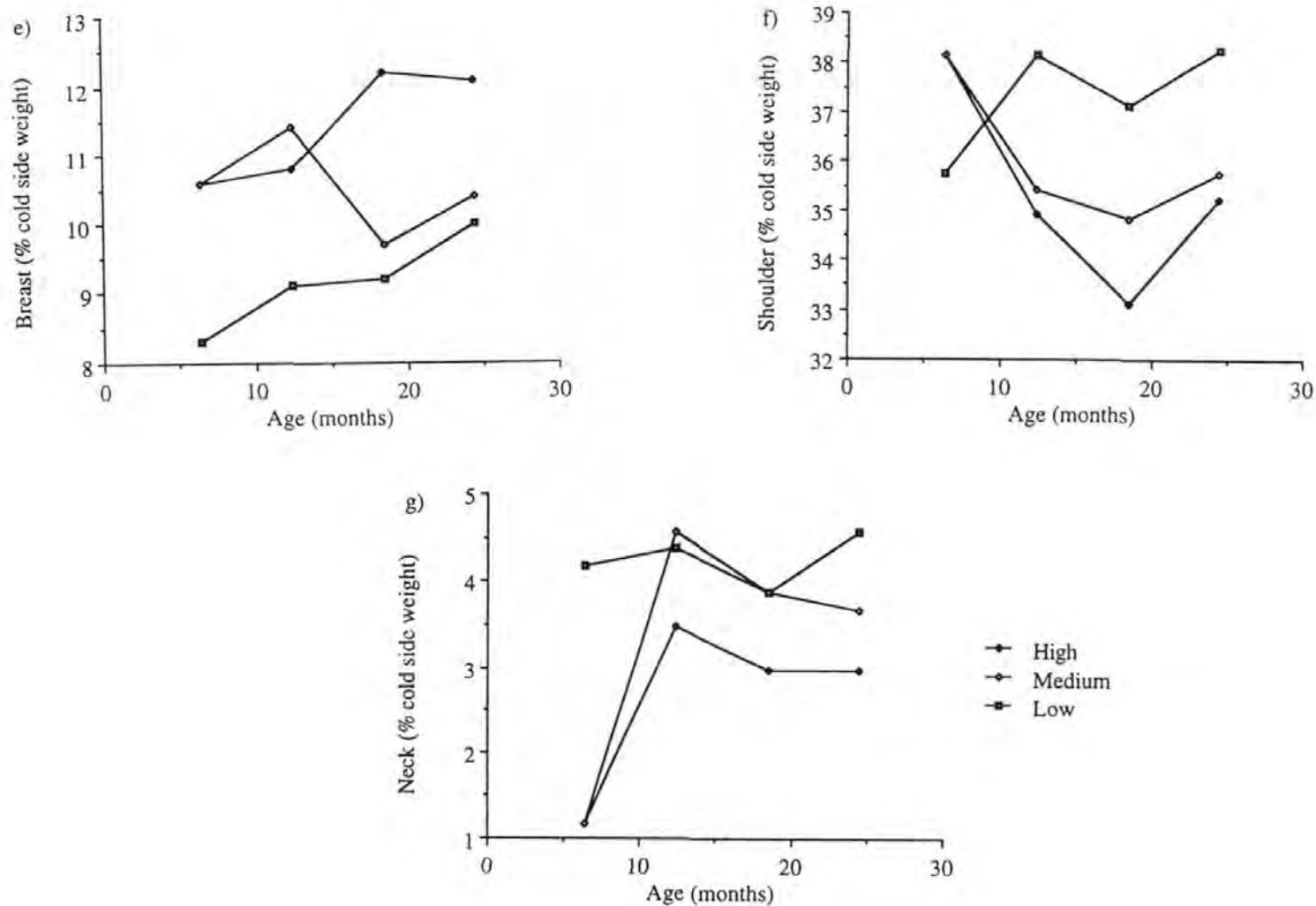
Figure 3.12 (continued)

The effect of plane of nutrition from six to 24 months of age on the weight of commercial carcass joints of Angora wether goats - expressed as a proportion of cold side weight

(b) Medium plane

The weights of all of the joints increased up to 24 months of age in the **M** plane goats but there were no significant differences between consecutive treatment groups due to the smaller magnitude of the increases relative to those in the **H** plane goats (Table 3.8, Figure 3.10).

The carcasses of the **M** plane goats exhibited the same pattern of centripetal development as those of the **H** plane goats. The shoulder had increased the least at 24 months of age over its value at six months (105.3%) followed by the leg (113.7%), the breast (115.0%), the chump (135.4%), the loin (155.5%) and the best end (173.5%) (Table 3.9, Figure 3.11b).

(c) Low plane

Due to the relatively small increases in the weights of the joints of the **L** plane goats compared with those of the **M** and **H** plane goats there were no significant differences between treatment groups, with the exception of the leg which increased significantly from 1.103kg in group 6L to 1.620kg in group 24L (Table 3.8). The leg was the only joint not affected by the poor feed intakes of the **L** plane goats. Its weight increased steadily with age (Figure 3.10a) while all other joints lost weight between 12 and 18 months and regained it by 24 months of age (Figures 3.10b to g). This emphasised the early maturing nature of the leg joint.

The relative immaturity of the **L** plane carcasses at each age compared with the **M** and **H** plane carcasses was illustrated by an almost complete reversal of the order of proportional development in the **L** plane goats (Figure 3.11c). By 24 months of age the breast had increased the most relative to its weight at six months (70.1%) followed by the shoulder (50.0%). The loin, chump and leg had increased by only 46.5%, 46.7% and 46.9% each and the best end was the least developed joint, having increased its weight by only 32.5%. Consequently the leg, shoulder and breast tended to increase as proportions of cold side weight, the chump remained approximately constant and the loin and best end tended to decrease (Table 3.10, Figure 3.12).

Under conditions of nutrient insufficiency the early maturing joints had priority over the available nutrients while the growth of the later maturing joints was restricted. Consequently there was a greater effect of increasing the plane of nutrition from **L** to **H** on the later maturing loin and best end joints than on the earlier maturing leg and shoulder joints (Figure 3.10). On the **L** plane of nutrition the carcasses were generally thinner with a greater proportion of leg and shoulder joints while on the **H** plane of nutrition the carcasses were more blocky and better filled with a greater proportion of loin, breast and best end joints (Table 3.10).

The effect of plane of nutrition on joint weight was mainly due to increased fat deposition on the **H** and **M** planes of nutrition compared with the **L** plane. There was little difference in the weights of the fat free joints at any age between the three planes of nutrition (Table 3.11, Figure 3.13). The greatest effect of plane of nutrition on the fat free joints was seen at 18 months of age, but by 24 months of age the growth of the fat free carcass in the **H** plane goats had plateaued while that of the **L** plane goats was still increasing, resulting in smaller differences in fat free joint weights at 24 months compared with 18 months of age.

| | Treatment group | | | | | | | | | | | s.e. | Significance of effect of | | |
| | High | | | | Medium | | | Low | | | | | A | N | I |
	6H/M	12H	18H	24H	12M	18M	24M	6L	12L	18L	24L				
Leg	0.742a	1.365cde	1.705fg	1.780g	1.118bcd	1.174bcd	1.542efg	0.915ab	1.052abc	1.074abcd	1.406def	0.02	***	***	***
Chump	0.239a	0.377bc	0.535de	0.614e	0.314abc	0.365abc	0.527de	0.262ab	0.345abc	0.278abc	0.406cd	0.01	***	***	***
Loin	0.273a	0.532bcde	0.613de	0.706e	0.376ac	0.439acd	0.595cde	0.310ab	0.417acd	0.342ab	0.470acd	0. 01	***	***	*
Best end	0.178a	0.384cd	0.413d	0.417d	0.312bcd	0.278abc	0.409d	0.214ab	0.262abc	0.268abc	0.316bcd	0.01	***	***	**
Breast	0.219a	0.404bcd	0.542d	0.441cd	0.359abc	0.317abc	0.380bc	0.214a	0.268ab	0.271ab	0.384bc	0.01	***	***	**
Shoulder	1.106a	1.900def	2.414g	2.437g	1.570bcd	1.678cde	2.185fg	1.193ab	1.482acd	1.399abc	2.016efg	0.03	***	***	***

Means in the same row with the same superscript are not significantly different (P > 0.05)
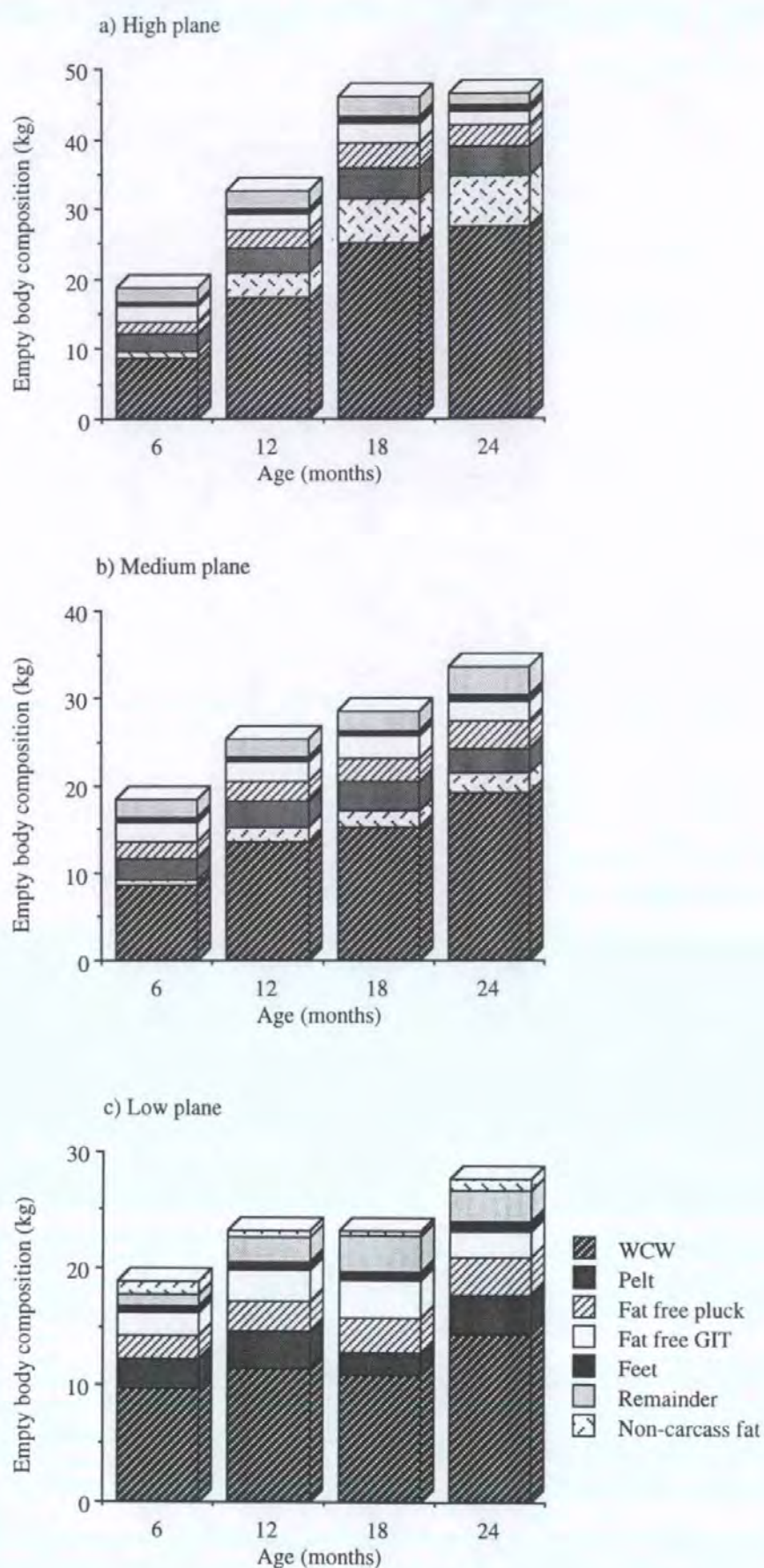
Table 3.11

Effect of age and plane of nutrition on the weight of fat-free commercial carcass joints (kg) of Angora wether goats (means of six goats)
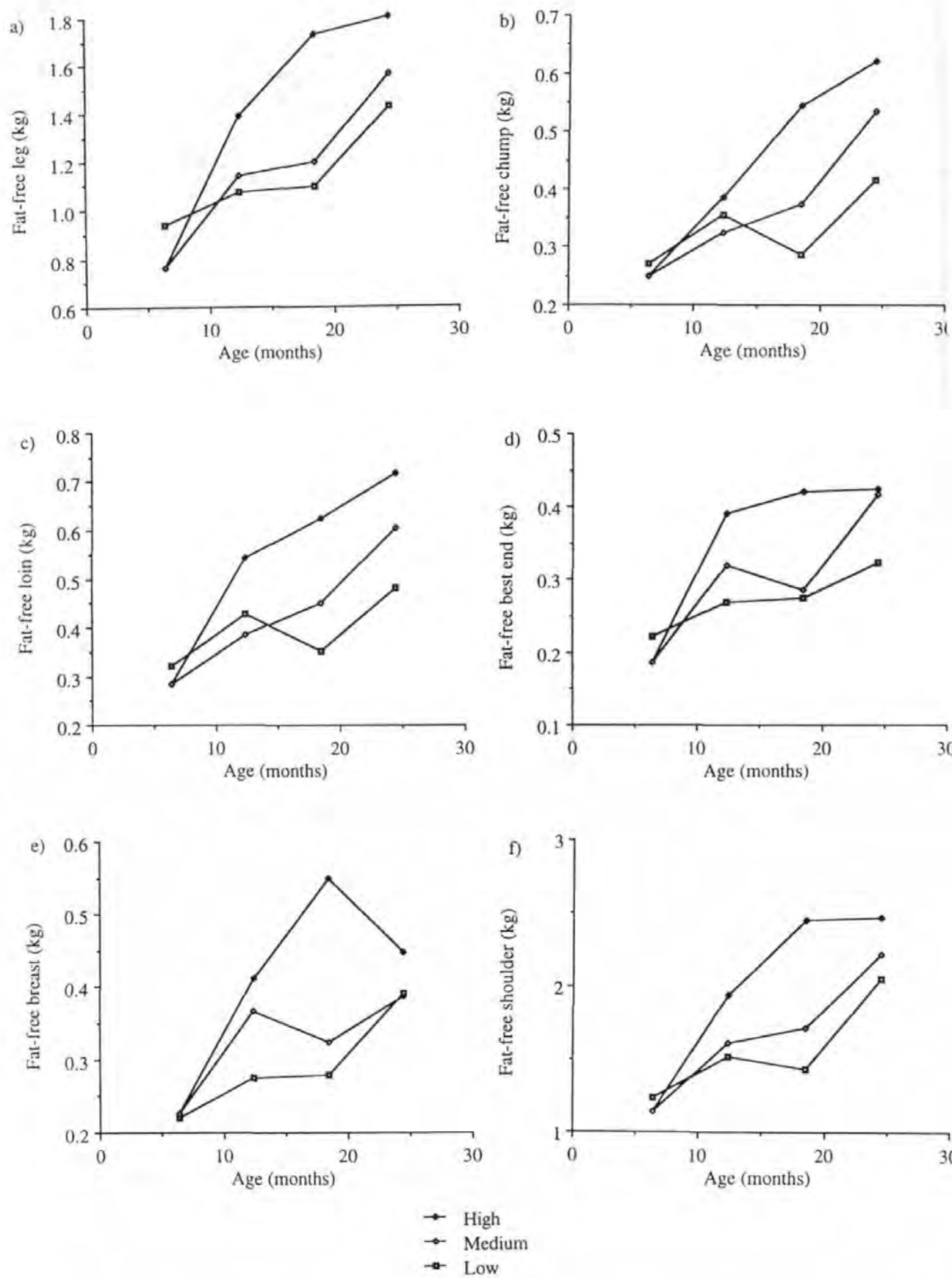
Figure 3.13

The effect of age and plane of nutrition on the weight of fat-free commercial carcass joints of Angora wether goats

3.3.6 Allometric growth of the British Angora wether goat from six to 24 months of age (16 to 60kg empty body weight)

For each plane of nutrition the 24 observations derived from the slaughtered goats for each body component were applied to the allometric model

$$y = ax^b$$

in order to describe the growth of each part of the body or carcass (y) in relation to the growth of the whole empty body or cold carcass (x). In the above equation b was the allometric coefficient and a was a constant. The logarithmic form of the equation

$$\log_{10} y = \log_{10} a + b \log_{10} x$$

was used to determine the statistical significance of the fit of the data to the line produced (Appendix II) and to compare the allometric coefficients for each body or carcass component on the three planes of nutrition (Tables 3.12 to 3.14; Appendix II).

The order of maturity of the components of the empty body was demonstrated using the data derived from the H plane goats since that plane of nutrition encompassed the widest range of empty body weights (16 to 60kg) and therefore the most mature animals. The allometric coefficients were ranked in increasing order of magnitude, the early maturing components having the lowest coefficients and the late maturing components having the highest coefficients (Table 3.12). The most early maturing components were the lungs with an allometric coefficient of 0.173. The latest maturing component was the total body fat with an allometric coefficient of 1.581 (Figure 3.14). In general the vital organs - lungs, liver, heart and kidneys - were the earliest maturing body components, followed by the external offal - feet, pelt and head, the warm carcass and finally the body fat.

Body component (y)	Allometric coefficient (b)			Significance of difference between allometric coefficients		
	High	Medium	Low	H v M	H v L	M v L
Lungs	0.173	-0.039	1.538			
Liver & spleen	0.588	0.442	1.411	NS	***	***
Kidneys	0.614	0.530	1.017	NS	*	***
Feet	0.684	0.759	0.916	NS	*	NS
Head	0.710	1.039	0.849	*	NS	NS
Heart	0.755	0.900	1.241	NS	*	NS
Pelt	0.764	0.724	0.797	NS	NS	NS
WCW	1.217	1.281	1.041	NS	*	**
Total body fat	1.581	1.642	0.132	NS		

Table 3.12

Allometric coefficients (b) for the growth of main body components and organs (y) relative to the growth of the empty body (x)
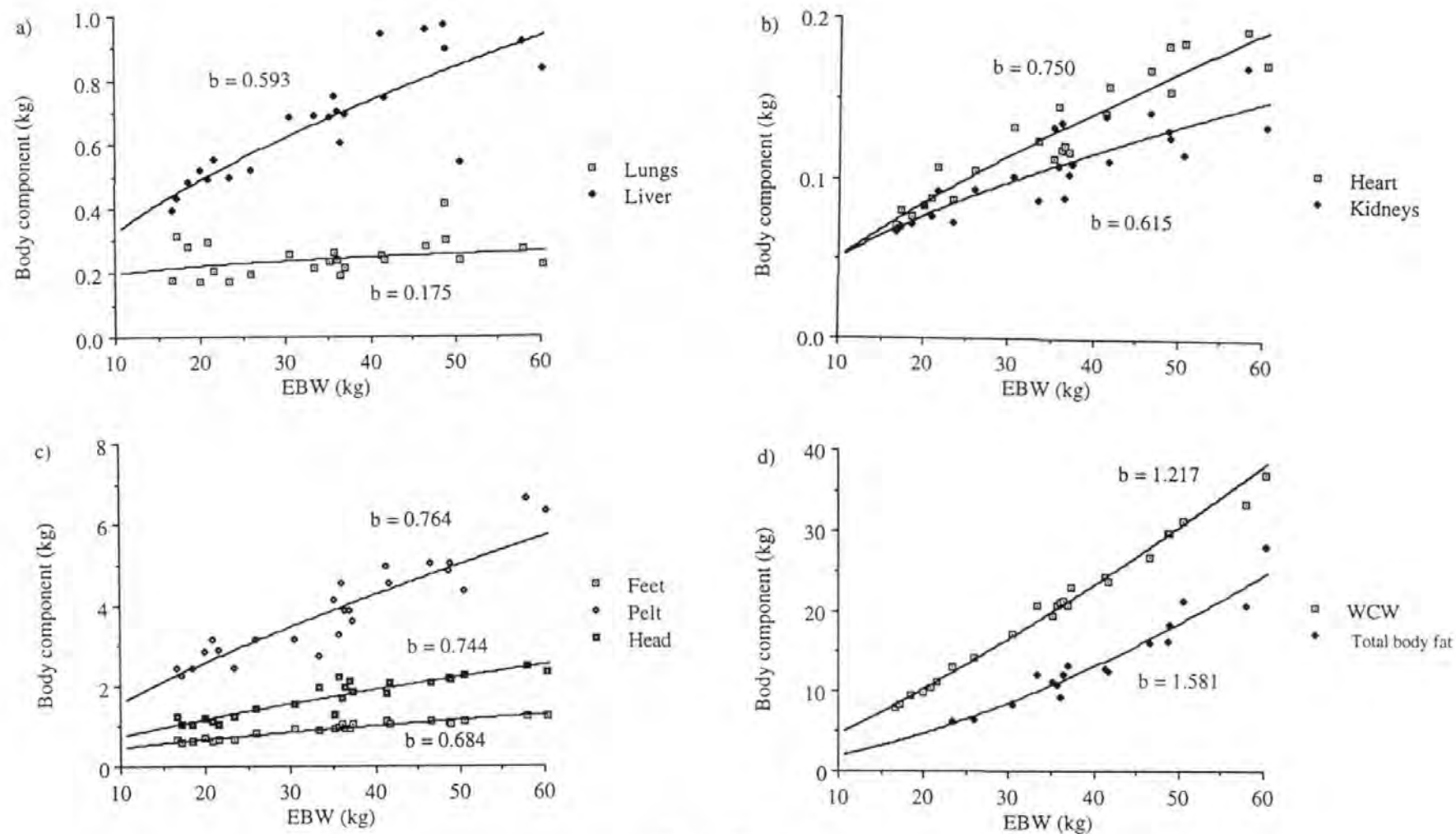
Figure 3.14

Allometric curves for the growth of main body components and organs (y) relative to the growth of the empty body (x)

of goats reared from six to 24 months of age on a high plane of nutrition

The allometric development of the dissected half carcass tissues with respect to cold carcass weight was examined in the same way (Table 3.13, Figure 3.15). Bone was the earliest maturing carcass tissue (b = 0.586) followed by lean (0.786), carcass dissectible fat (SCF plus IMF, 1.320) and KKCF was the latest maturing carcass tissue (1.550). When the carcass dissectible fat was examined as two separate depots IMF was earlier maturing than SCF, with b values of 1.214 and 1.403 respectively.

The commercial carcass joints matured in the following order with respect to cold carcass weight; shoulder (0.841), leg (0.847), chump (0.963), loin (1.063), breast (1.077) and best end (1.149) (Figure 3.16).

Body component (y)	Allometric coefficient (b)			Significance of difference between allometric coefficients		
	High	Medium	Low	H v M	H v L	M v L
Carcass bone	0.586	0.800	0.784	NS	NS	NS
Carcass lean	0.786	0.859	1.337	NS	***	***
Carcass dissectible fat	1.320	1.267	0.719	NS	**	**
IMF	1.214	1.193	0.816	NS	NS	NS
SCF	1.403	1.327	0.671	NS	**	*
KKCF	1.550	1.483	-0.217	NS		
Shoulder	0.841	0.871	1.074	NS	**	**
Leg	0.847	0.909	1.031	NS	*	NS
Chump	0.963	1.007	1.148	NS	NS	NS
Loin	1.063	1.111	1.176	NS	NS	NS
Breast	1.077	0.956	1.229	NS	NS	*
Best end	1.149	1.265	0.987	NS	NS	*

Table 3.13

Allometric coefficients (b) for the growth of half carcass tissues and commercial joints (y) relative to the growth of the cold carcass (x)

Figure 3.15

Allometric curves for the growth of half carcass tissues (y) relative to the growth of the cold carcass (x) of goats reared from six to 24 months of age on a high plane of nutrition
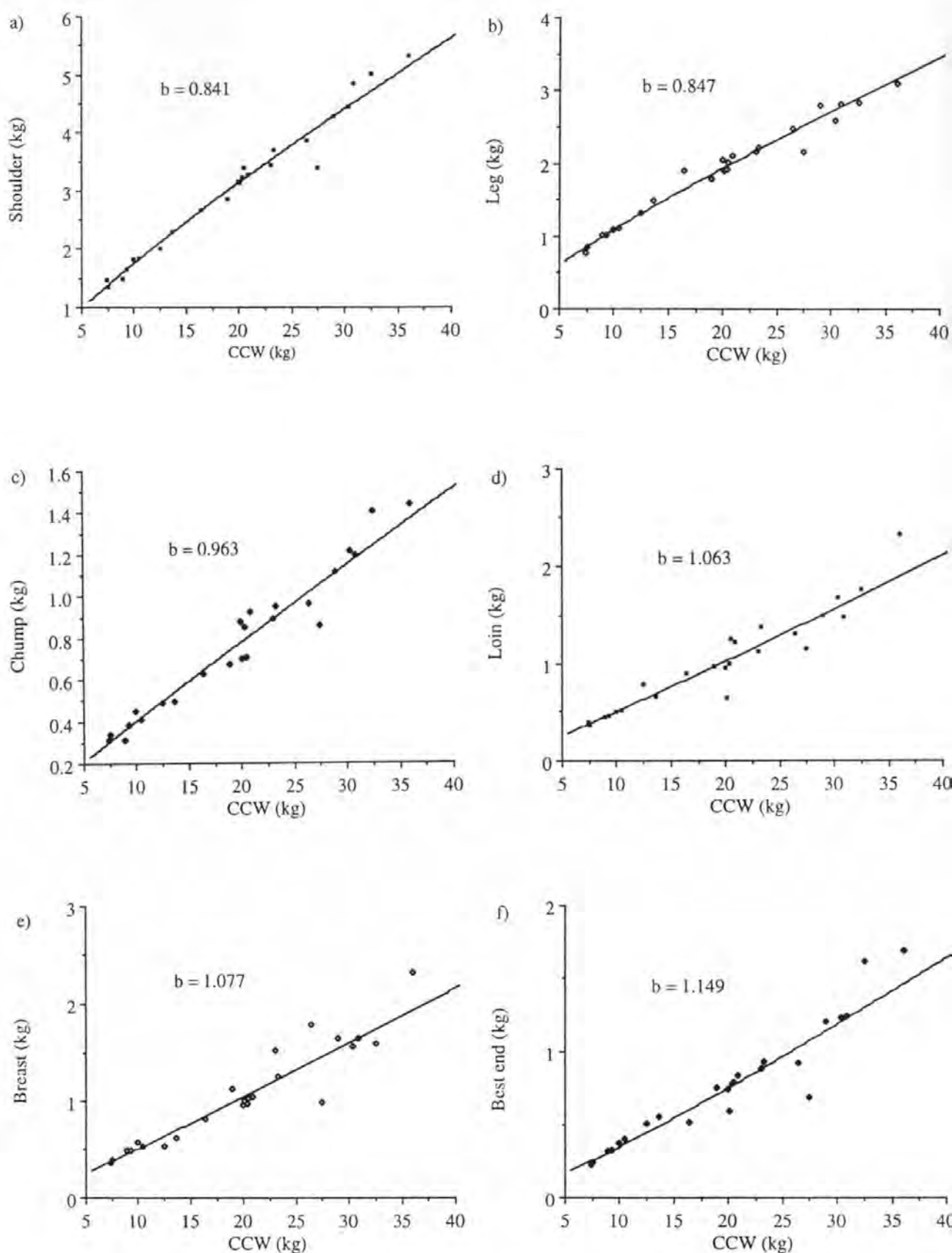
Figure 3.16

Allometric curves for the growth of commercial carcass joints (y) relative to the growth
of the cold carcass (x)

The body fat depots also showed a distinct order of maturity with respect to empty body weight. Visceral fat was the earliest maturing depot (1.123) followed by mesenteric fat (1.274), IMF (1.548), SCF (1.787), KKCF (1.896) and omental fat (1.958) (Table 3.14, Figure 3.17). The allometric coefficients for KKCF and omental fat were so similar for the H plane goats that it was impossible to say with any certainty which was the earlier maturing. However, in the M plane goats KKCF was more rapidly developing than omental fat, and in the L plane goats KKCF was more rapidly mobilised than omental fat. This suggested that KKCF is actually the latest maturing fat depot and as such was mobilised in the H plane goats when their feed intakes fell below maintenance, resulting in a slightly greater allometric coefficient for omental fat.

Body component (y)	Allometric coefficient (b)			Significance of difference between allometric coefficients		
	High	Medium	Low	H v M	H v L	M v L
Visceral fat	1.123	1.794	-0.532	NS		
Mesenteric fat	1.274	0.892	0.526	NS		
IMF	1.548	1.582	0.808	NS	**	*
SCF	1.787	1.763	0.468	NS		
KKCF	1.896	1.945	-0.737	NS		
Omental fat	1.958	1.934	-0.040	NS		

Table 3.14

Allometric coefficients (b) for the growth of body and carcass fat depots (y) relative to the growth of the empty body (x)
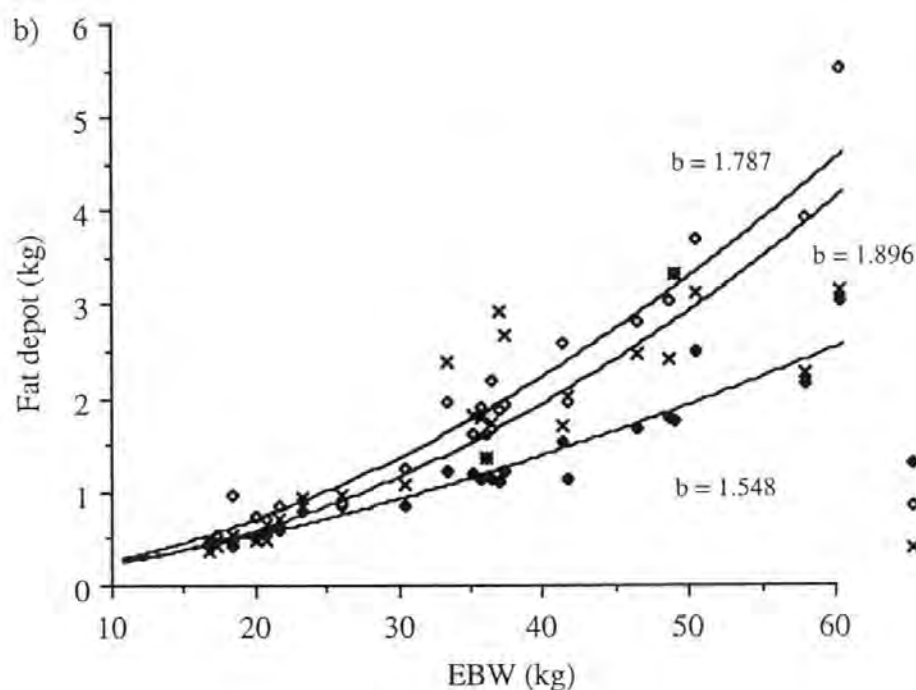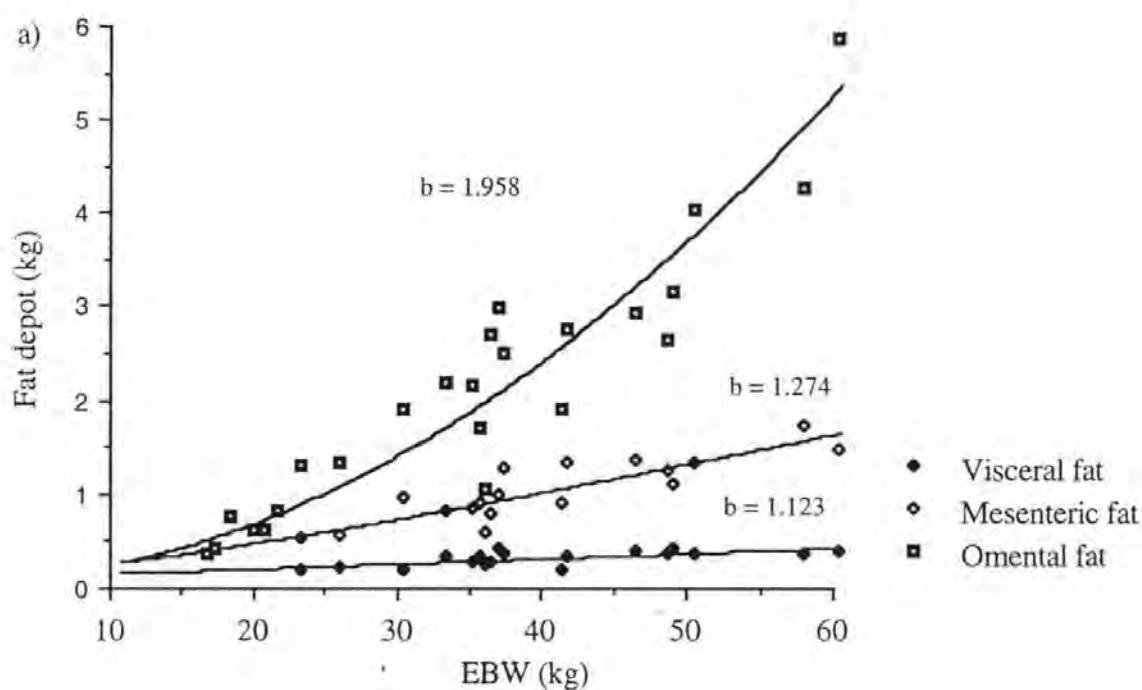
Figure 3.17

Allometric curves for the growth of body and carcass fat depots (y) relative to the growth of the empty body (x)

3.3.7 The effect of plane of nutrition on the allometric growth of the British Angora wether goat

For most of the linearised allometric equations the intercept and the gradient were significantly different from zero and the regression line represented a significant proportion of the variation in the data (Appendix II). The exceptions were those equations with very low allometric coefficients - the growth of the lungs with respect to EBW in the **H** and **M** plane goats (Appendix II, Table 1.1), the growth of KKCF with respect to CCW in the **L** plane goats (Appendix II, Table 1.2) and the growth of all fat depots with respect to EBW in the **L** plane goats with the exception of IMF (Appendix II, Table 1.3). In each case the gradient was not significantly different from zero and the regression line did not represent a significant proportion of the variation in the data. Consequently these regression equations could not be statistically compared with those formulated for the other planes of nutrition (Tables 3.12 to 3.14). The remaining equations were compared, in pairs, using analysis of covariance (Snedecor and Cochran, 1967) to determine the effect of varying the plane of nutrition on the allometric relationships (Appendix II).

Reducing the plane of nutrition from **H** to **L** tended to reverse the order of the relative growth rates (b) of the main body components with respect to EBW (Figure 3.18). In the **H** plane goats the warm carcass and total body fat were the most rapidly developing body components while the vital organs were the least rapidly developing with respect to the growth of the whole empty body. In the **L** plane goats the vital organs developed the most rapidly while total body fat was the most slowly developing component. Consequently the b values tended to increase with decreasing plane of nutrition for the early maturing parts and decreased with decreasing plane of nutrition for the late maturing parts (Table 3.12).

There were significant differences between the **L** and **H** plane goats in the b values for all body components except for the head and the pelt which did not differ significantly, and the lungs and total body fat which could not be compared statistically (Table 3.12). There were also significant differences between the **L** and **M** plane goats in the b values for the liver and spleen, the kidneys and the warm carcass, while the **H** and **M** plane goats differed

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significantly only between the b values for the head.
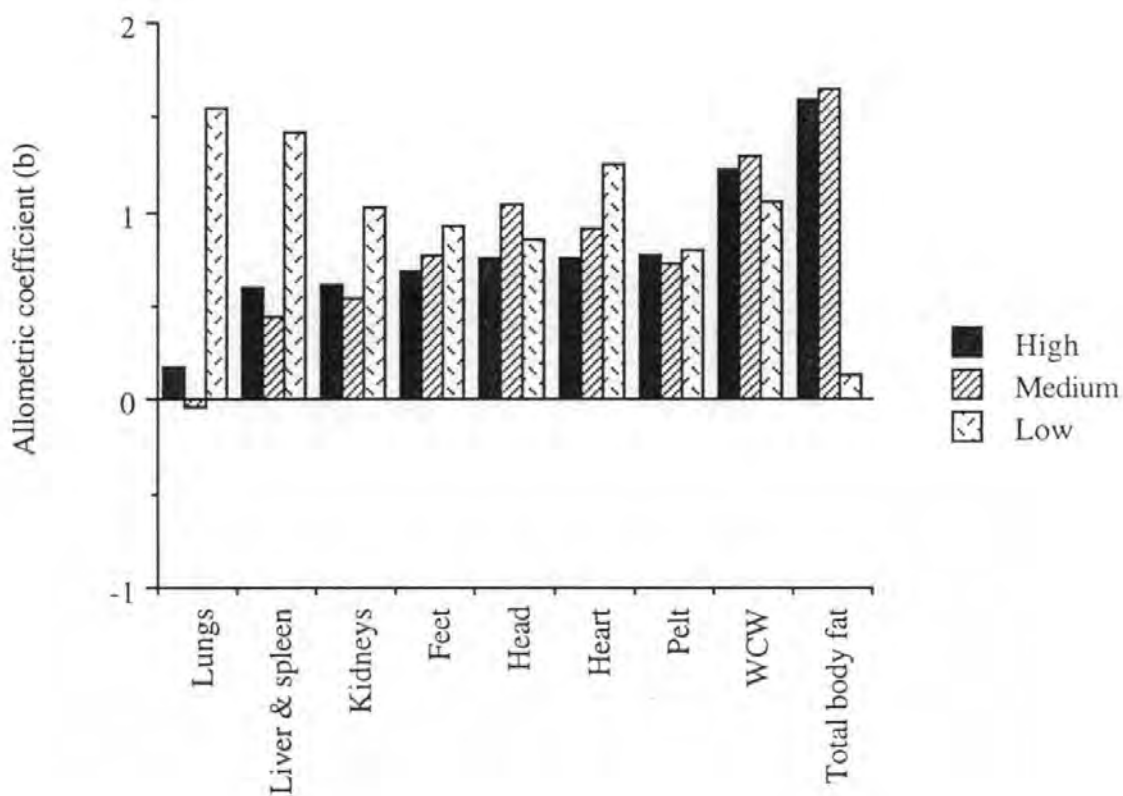
Figure 3.18

The effect of plane of nutrition on the allometric growth of the main body components and organs relative to the growth of the empty body

Varying the plane of nutrition had similar effects on the allometric development of the carcass tissues with respect to CCW (Figure 3.19). The relative growth rate of the early maturing carcass bone tended to increase with decreasing plane of nutrition from 0.586 in the H plane goats to 0.784 in the L plane goats, but the difference was not significant (Table 3.13).The relative growth rate of carcass lean increased with decreasing plane of nutrition. There was a significant increase from 0.786 in the H plane goats and 0.859 in the M plane goats to 1.337 in the L plane goats (P < 0.001). The allometric coefficient of the late maturing carcass dissectible fat decreased with decreasing plane of nutrition from 1.320 in the H plane goats to 0.719 in the L plane goats. The L value was significantly lower than both the M and H values (P < 0.01). The significant differences were mainly attributable to differences in the relative growth rate of the later maturing SCF which increased from 0.671 in the L plane goats to 1.403 in the H plane goats. Although the earlier maturing IMF showed the same trend of increasing b value with increasing plane of nutrition the differences were not significant. The greatest effect of plane of nutrition was on the relative growth rate of KKCF which decreased with increasing CCW in the L plane goats (b = -0.217) while increasing rapidly with increasing CCW in the M and H plane goats (b = 1.483 and 1.550 respectively). The H and M planes did not differ significantly and the L plane could not be statistically compared.

In general on the H plane of nutrition KKCF was the most rapidly developing carcass tissue relative to CCW and bone was the least rapidly developing. On the L plane of nutrition bone, being the earliest maturing tissue, was still the least rapidly developing carcass tissue. For all other components the order of relative growth rate was opposite to that for the H plane goats - lean was the most rapidly developing carcass tissue and KKCF was the least rapidly developing relative to CCW.

The relative growth rates of the earlier maturing commercial carcass joints with respect to CCW tended to increase with decreasing plane of nutrition while that of the latest maturing joint, the best end, tended to decrease with decreasing plane of nutrition (Table 3.13, Figure 3.20). In general the allometric coefficients for the L plane joints were greater than for the M and H plane joints due to the influence of KKCF on CCW. The relatively more rapid growth

of KKCF in the **H** plane carcasses caused the commercial joints to develop relatively less rapidly than in the **L** plane carcasses in which KKCF actually declined with increasing CCW (Figure 3.21).
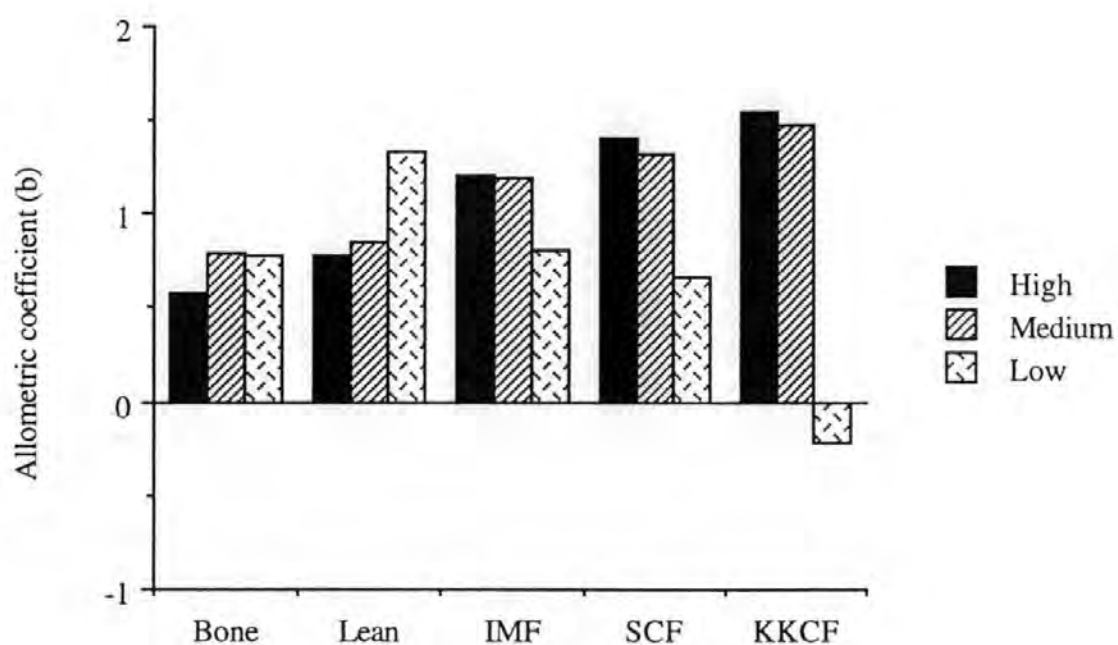
Figure 3.19

The effect of plane of nutrition on the allometric growth of the half carcass tissues relative to the growth of the cold carcass
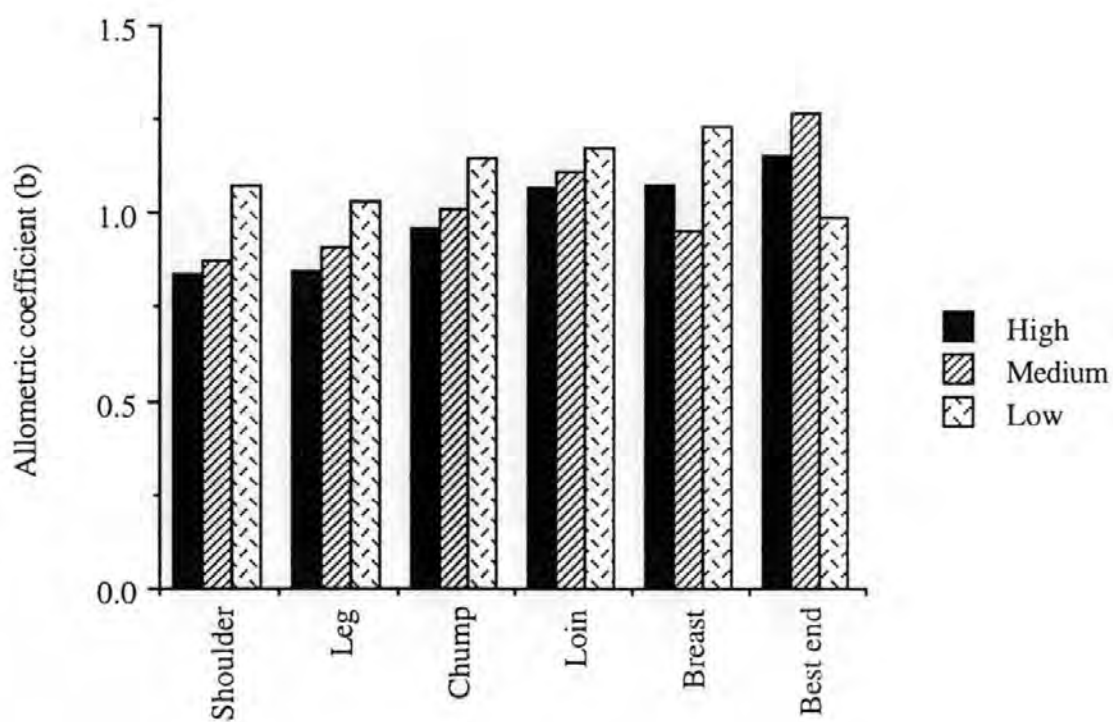
Figure 3.20

The effect of plane of nutrition on the allometric growth of the commercial carcass joints relative to the growth of the cold carcass

There were no significant differences between the **M** and **H** plane goats in the relative growth rates of the fat depots with respect to EBW (Table 3.14) but there appeared to be an effect of the **L** plane of nutrition. The relative growth rates of the fat depots in the **L** plane goats were lower than in the **M** and **H** plane goats (Figure 3.21), but with the exception of IMF could not be compared by covariance analysis. The allometric growth of IMF was significantly lower for the **L** plane goats (0.808) than for the **M** plane goats (1.582; $P < 0.05$) and the **H** plane goats (1.548; $P < 0.01$). The late maturing non-carcass fat depots, omental and KKCF, had negative b values of -0.040 and -0.737 respectively which suggested that they were mobilised in preference to the earlier maturing carcass fat to compensate for the nutrient insufficiency suffered by the **L** plane goats. The order of relative growth rates of the fat depots with respect to EBW was therefore opposite to that for the **M** and **H** plane goats i.e. the earlier maturing depots were the most rapidly developing while the late maturing depots were the least rapidly developing or most rapidly depleting depots, suggesting that the order of fat mobilisation was the exact opposite of fat deposition. This was true with the exceptions of visceral and mesenteric fat which appeared to be early maturing in the **H** plane goats but were still less rapidly developing than IMF in the **L** plane goats. This may have been due to the high proportion of missing data for these fat depots.

The order of development of the fat depots with respect to the growth of total body fat, excluding visceral and mesenteric fat, was not significantly affected by plane of nutrition (Table 3.15, Figure 3.22). In the **M** and **H** plane goats omental fat appeared to be slightly later maturing than KKCF but the allometric coefficients for the two depots were very similar. Previous evidence (Section 6.1) and the order of maturity given for the **L** plane goats in Table 3.15 suggests that KKCF is the latest maturing fat depot and as such the first to be mobilised when nutrient intake is insufficient.

Body component (y)	Allometric coefficient (b)			Significance of difference between allometric coefficients		
	High	Medium	Low	H v M	H v L	M v L
IMF	0.821	0.842	0.610	NS	NS	NS
SCF	0.968	0.974	0.760	NS	NS	NS
Omental fat	1.103	1.093	1.408	NS	NS	NS
KKCF	1.065	1.070	1.568	NS	*	*

Table 3.15

Allometric coefficients (b) for the growth of half carcass IMF, SCF, total KKCF and omental fat (y) relative to the growth of the summed weight of the four depots (x)

There were no significant differences between the **H** and **M** planes of nutrition in the growth of any of the fat depots relative to the growth of the summed weights of the four depots, although the allometric coefficients for the earlier maturing depots were slightly greater for the **M** plane goats while that for the late maturing omental fat was slightly greater for the **H** plane goats. In the **L** plane goats the relative growth of both IMF and SCF was lower while that of KKCF and omental fat was higher than for the other two planes of nutrition, and the differences between the allometric coefficients for KKCF were significant ($P < 0.05$). This result was the opposite to that which was expected and was attributable to the fact that omental and KKCF were mobilised more rapidly than IMF and SCF, and hence the greatest influence on the weight of total body fat (excluding visceral and mesenteric fat) was the variation in weight of the two latest maturing depots.
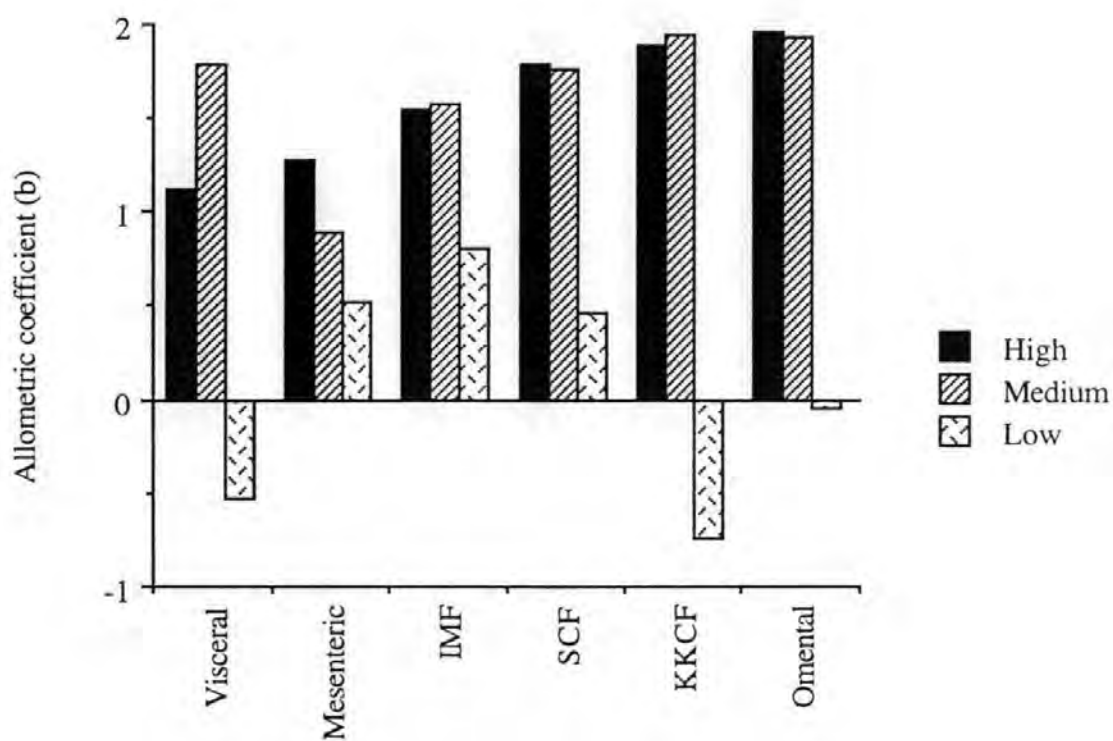
Figure 3.21

The effect of plane of nutrition on the allometric growth of the body and carcass fat depots relative to the growth of the empty body
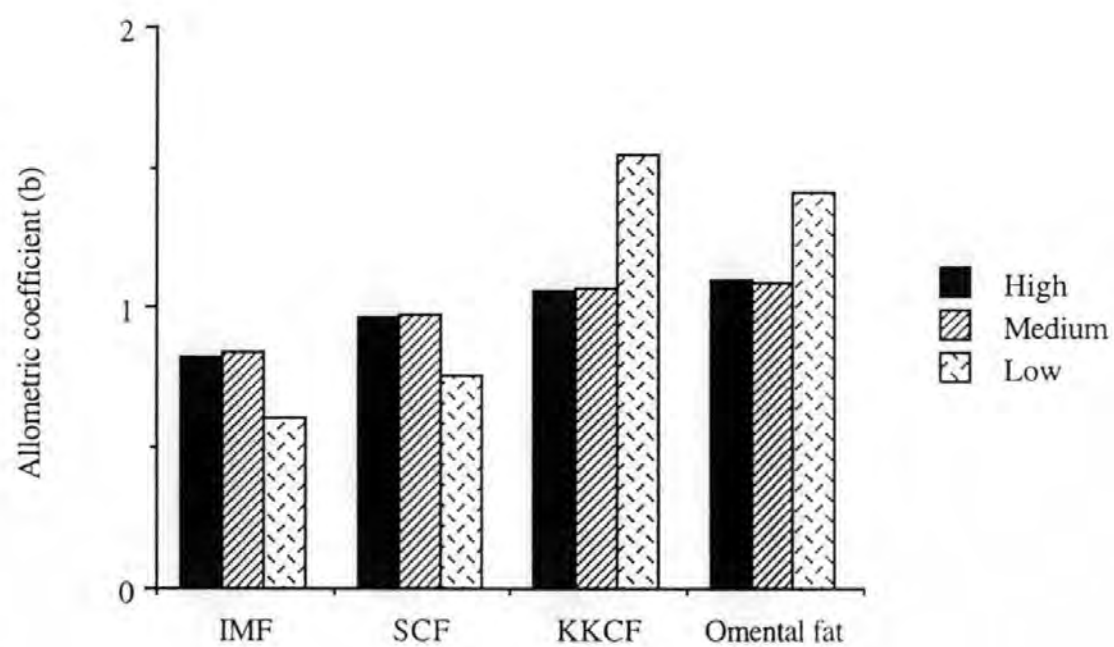
Figure 3.22

The effect of plane of nutrition on the allometric growth of half carcass IMF, half carcass
SCF, total KKCF and omental fat relative to the growth of the four fat depots

3.3.8 Allometric growth of the fat-free empty body and carcass of the British Angora wether goat

The classical approach to the analysis of the results which has been adhered to in the preceding sections has been criticised in more recent years since it takes no account of the influence of varying degree of body fatness on the relative growth rates of the remaining body tissues or of its effects on the body proportions of animals reared on different planes of nutrition (Wilson, 1960; Tulloh, 1963, Elsley *et al.*, 1964).

Therefore allometric equations were also formulated for the growth of each body and carcass component relative to the growth of the fat-free empty body or fat-free half carcass (dissected lean plus bone) respectively (Appendix II). The linear regressions of the weight of the lungs against fat-free EBW for both the M and H plane data were non-significant representations of the data (Appendix II, Table 3.1) and consequently could not be statistically compared with the L plane equation. Similarly for the L plane data the linear regressions of total body fat against fat-free EBW (Appendix II, Table 3.1), SCF and KKCF against lean plus bone (Appendix II, Table 3.2) and all fat depots except IMF and KKCF against fat-free EBW (Appendix II, Table 3.3) were non-significant representations of the data and could not be statistically compared with the corresponding M and H plane equations. The results of all other comparisons are listed in Appendix II.

There were no significant differences between the three planes of nutrition in the allometric coefficients (b) for the growth of the kidneys, feet, heart or pelt relative to the fat-free empty body (Table 3.16, Figure 3.23).

The growth of the liver plus spleen relative to that of the fat-free empty body was significantly greater for the L plane goats than for the M and H plane goats and the growth of the head relative to that of the fat-free empty body was significantly greater for the M than the L plane goats. It was possible that the presence of horns in the L plane goats affected this result. The growth of the fat-free cold carcass relative to that of the fat-free empty body was significantly lower for the L plane goats than for the M and H plane goats. This might be due

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to an effect of plane of nutrition on the development of intramuscular fat, which was not measured in this study, or to a permanent stunting effect of the L plane of nutrition on the growth of the fat-free carcass. However, the most likely explanation is the difference between the three planes of nutrition in the range of fat-free empty body weights (Figure 3.23g) with the more narrow range of values and lower ultimate maturity of the L plane goats affecting the fit of the regression line. Had the L plane goats been reared to the same degree of fat-free maturity as the M and H plane goats it is possible that a significant treatment effect on the relative growth of the fat-free carcass would not have been detected.

Body component (y)	Allometric coefficient (b)			Significance of difference between allometric coefficients		
	High	Medium	Low	H v M	H v L	M v L
Lungs	0.275	-0.024	1.346			
Liver & spleen	0.841	0.571	1.218	NS	*	**
Kidneys	0.881	0.699	0.854	NS	NS	NS
Feet	0.940	0.982	0.766	NS	NS	NS
Head	0.997	1.326	0.771	NS	NS	*
Heart	1.034	1.164	1.104	NS	NS	NS
Pelt	1.004	0.969	0.612	NS	NS	NS
Fat-free CCW	1.340	1.459	0.953	NS	**	***
Total body fat	2.376	2.287	-0.041	NS		

Table 3.16

Allometric coefficients (b) for the growth of the main body components and organs (y) relative to the growth of the fat-free empty body (x)
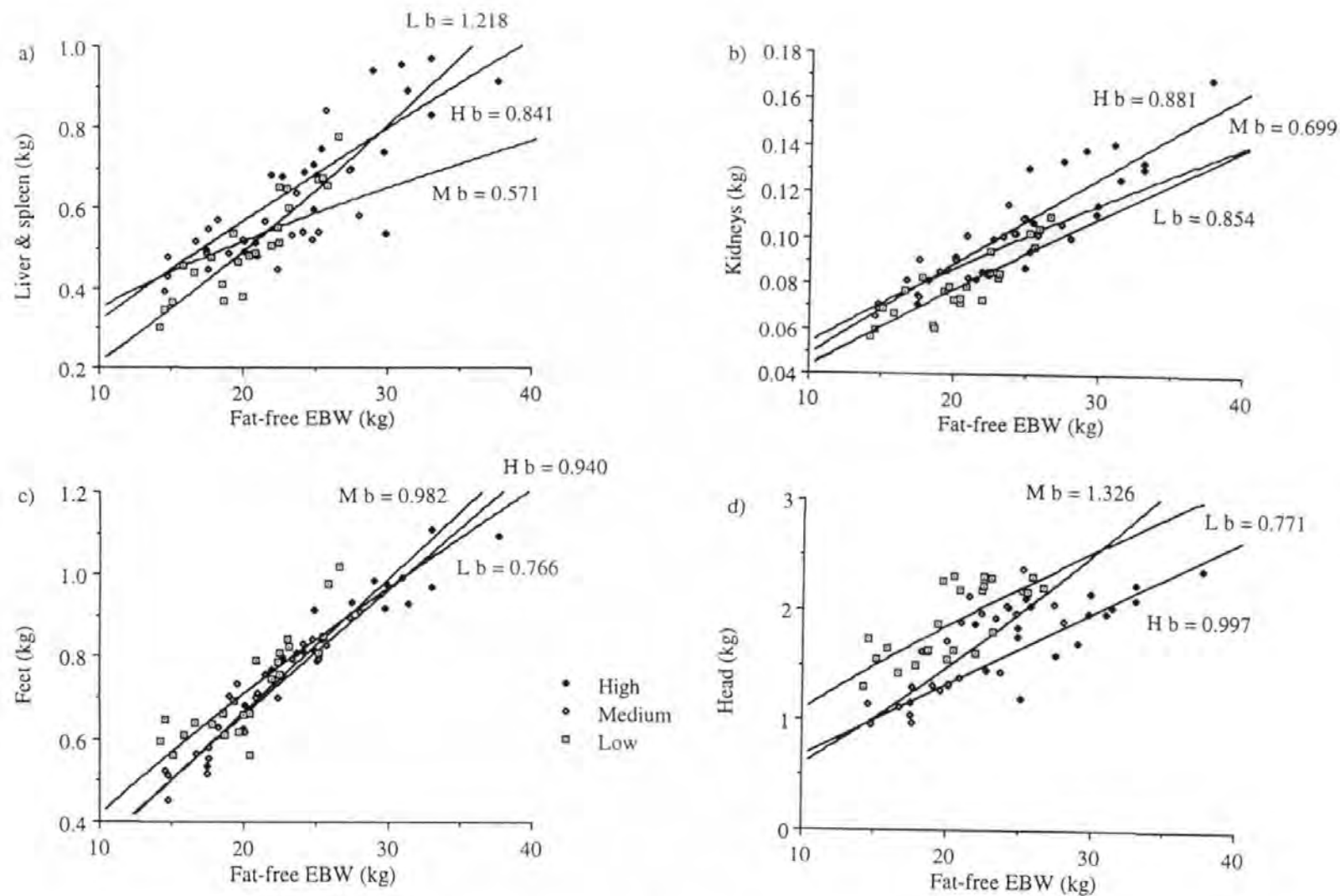
Figure 3.23

The effect of plane of nutrition on the allometric growth of the main body components and organs relative to the growth of the fat-free empty body
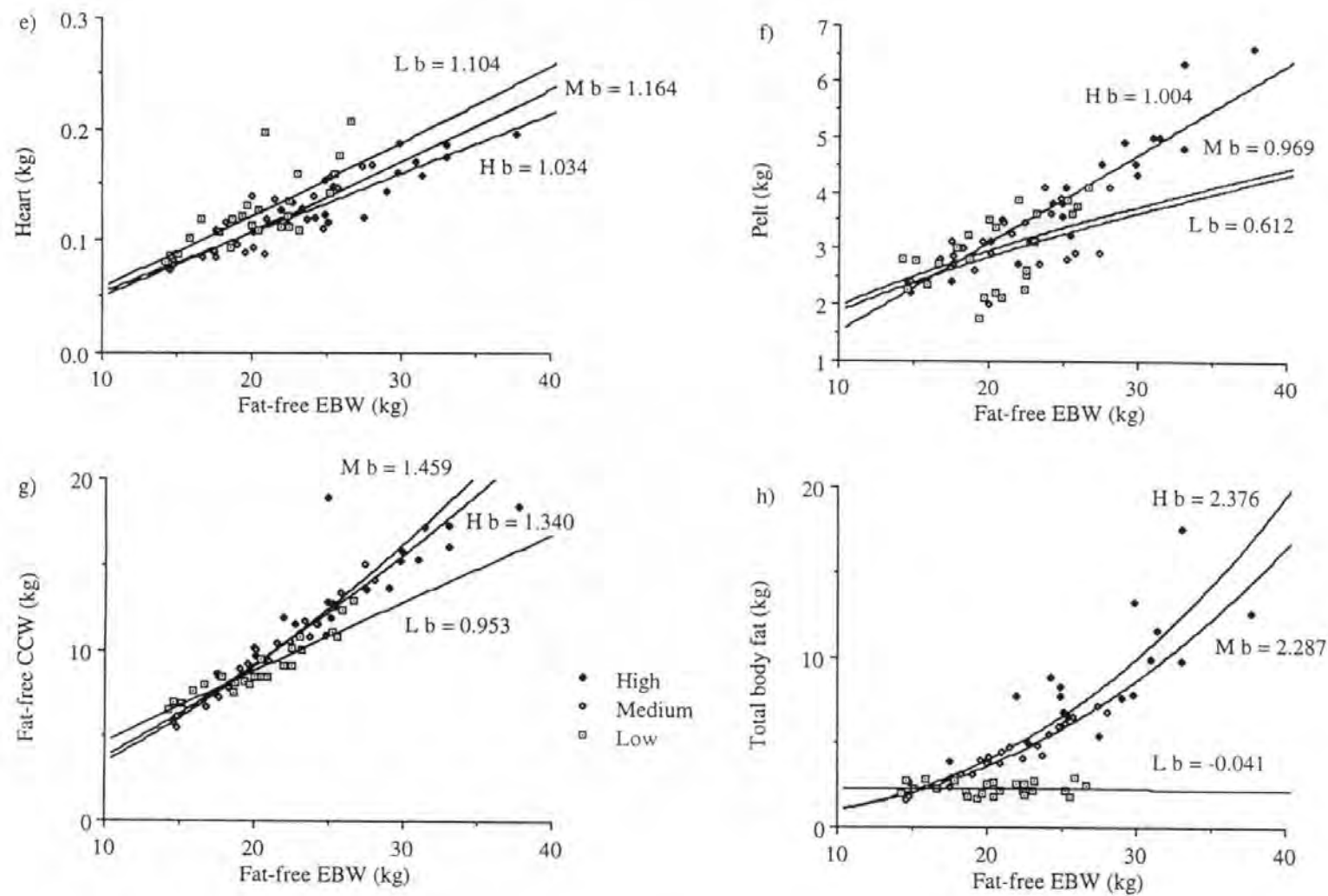
Figure 3.23 (continued)

The effect of plane of nutrition on the allometric growth of the main body components and organs relative to the growth of the fat-free empty body

Although the linear regression of total body fat against fat-free EBW was not a significant representation of the L plane data the trends illustrated in Figure 3.23 clearly indicated that the development of total body fat progressed relatively more slowly with respect to the growth of the fat-free empty body than it did in the M and H plane goats. There was no significant difference between the allometric coefficients for the M and H plane goats but there was a trend towards decreasing b value with decreasing plane of nutrition, suggesting an effect of plane of nutrition on the development of total body fat with respect to the growth of the fat-free empty body. This trend was also apparent in the allometric regressions of the individual fat depots against fat-free EBW (Table 3.17, Figure 3.24). The b values for the growth of IMF and KKCF relative to the growth of the fat-free empty body were significantly lower for the L plane goats than for the M and H plane goats.

Body component (y)	Allometric coefficient (b)			Significance of difference between allometric coefficients		
	High	Medium	Low	H v M	H v L	M v L
Visceral fat	1.225	2.158	-0.591	NS		
Mesenteric fat	1.580	1.041	0.391	NS		
IMF	2.065	2.014	0.662	NS	***	***
SCF	2.362	2.220	0.237	NS		
Total KKCF	2.472	2.462	-0.926	NS	***	***
Omental fat	2.542	2.445	-0.311	NS		

Table 3.17

Allometric coefficients (b) for the growth of body and half carcass fat depots (y) relative to the growth of the fat-free empty body (x)
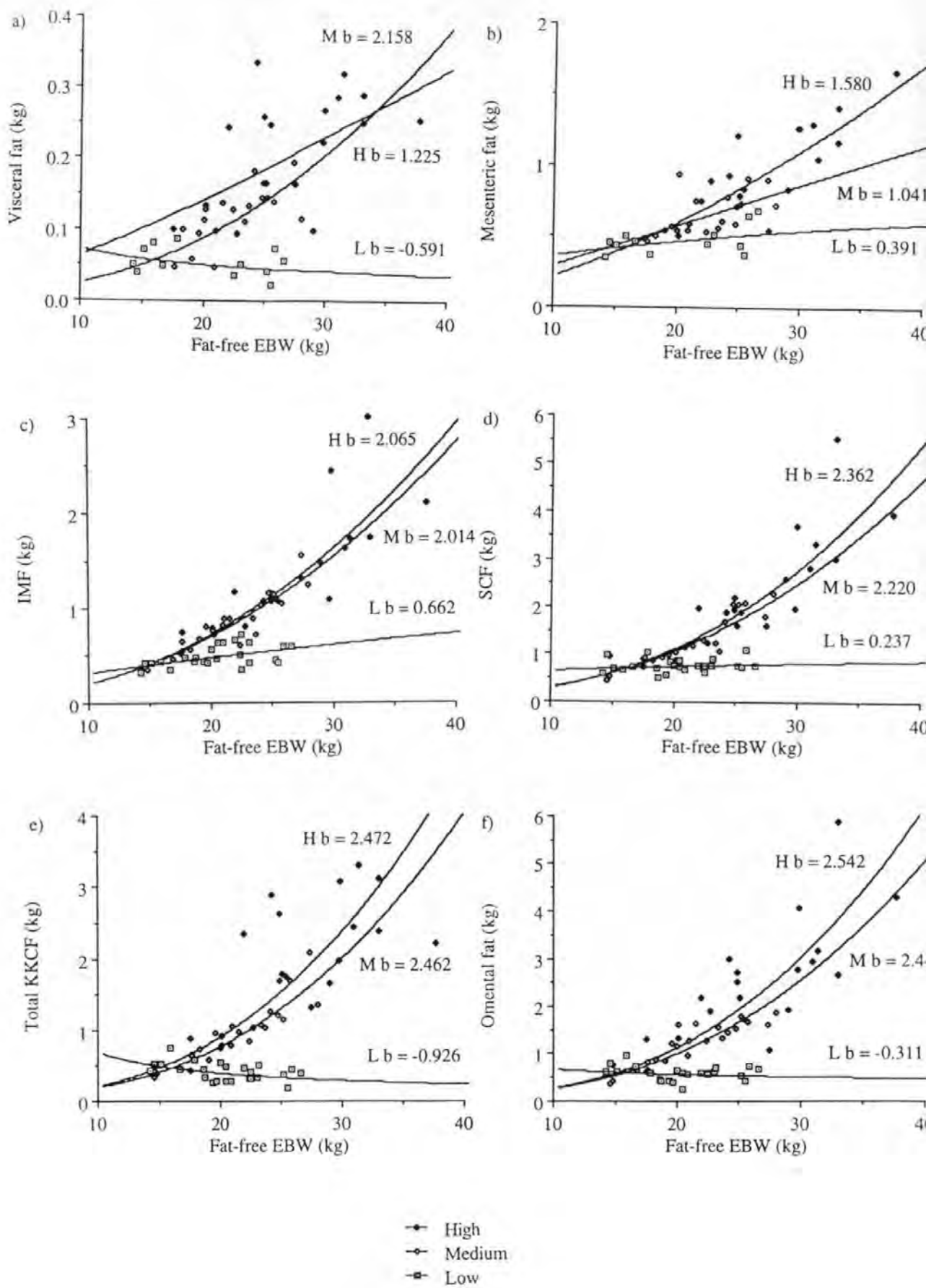
Figure 3.24

The effect of plane of nutrition on the allometric growth of body and half carcass fat depots
relative to the growth of the fat-free empty body

There was no significant effect of plane of nutrition on the growth of bone or lean relative to the growth of total lean plus bone in the dissected half carcass (Table 3.18, Figure 3.25a and b). However the growth of both carcass dissectible fat and IMF relative to half carcass lean plus bone was significantly lower for the L plane goats than for the M and H plane goats and there was a clear trend towards decreasing b value with decreasing plane of nutrition (Figure 3.25c and d). The same trend was apparent for SCF and KKCF (Figure 3.25e and f) but statistical comparisons could not be made between the L plane equations and those for the higher planes of nutrition.

Body component (y)	Allometric coefficient (b)			Significance of difference between allometric coefficients		
	High	Medium	Low	H v M	H v L	M v L
Carcass bone	0.778	0.951	0.685	NS	NS	NS
Carcass lean	1.077	1.021	1.149	NS	NS	NS
Carcass dissectible fat	1.720	1.423	0.408	NS	***	***
IMF	1.603	1.382	0.541	NS	***	**
SCF	1.815	1.468	0.337	NS		
KKCF	2.004	1.666	-0.430	NS		
Shoulder	0.833	0.950	1.017	NS	NS	NS
Leg	0.901	0.998	0.890	NS	NS	NS
Chump	0.982	1.102	1.003	NS	NS	NS
Loin	0.896	1.089	0.941	NS	NS	NS
Breast	0.851	0.687	1.146	NS	NS	*
Best end	0.993	1.202	0.850	NS	NS	*

Table 3.18

Allometric coefficients (b) for the growth of half carcass tissues and fat-free commercial joints (y) relative to the growth of half carcass lean plus bone (x)
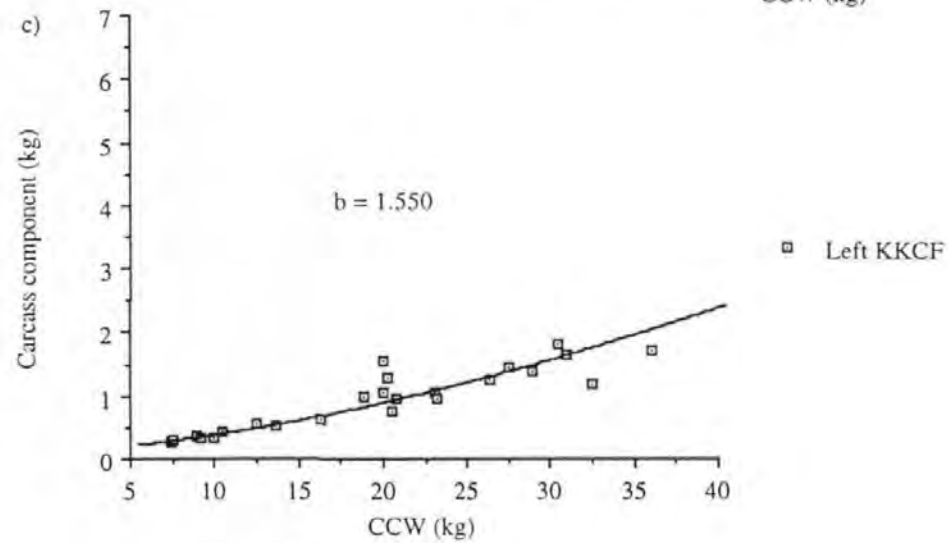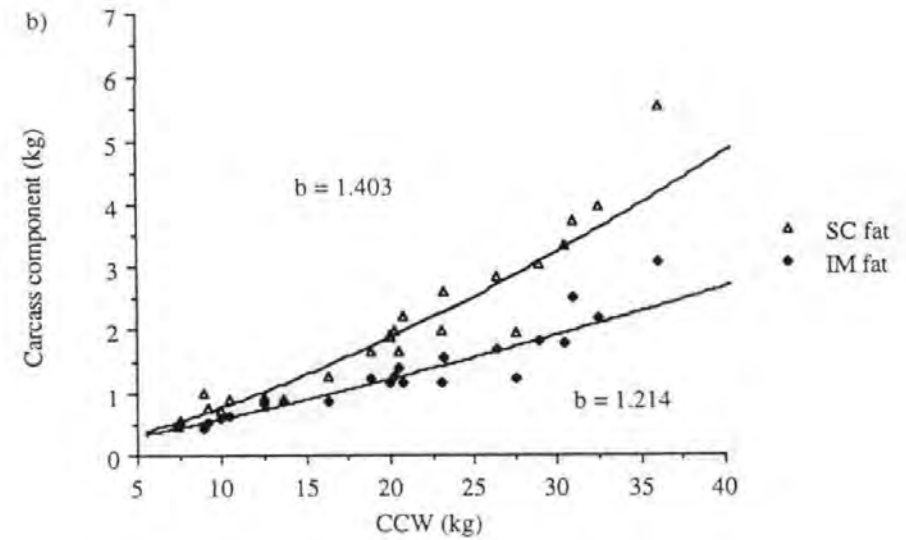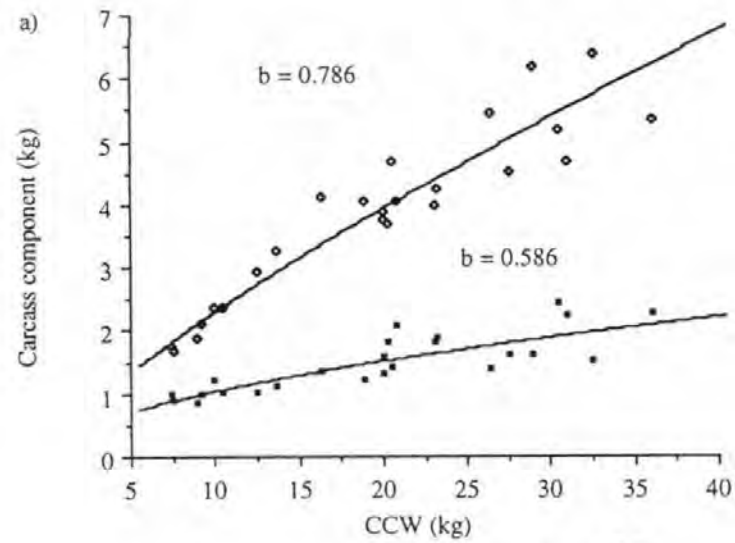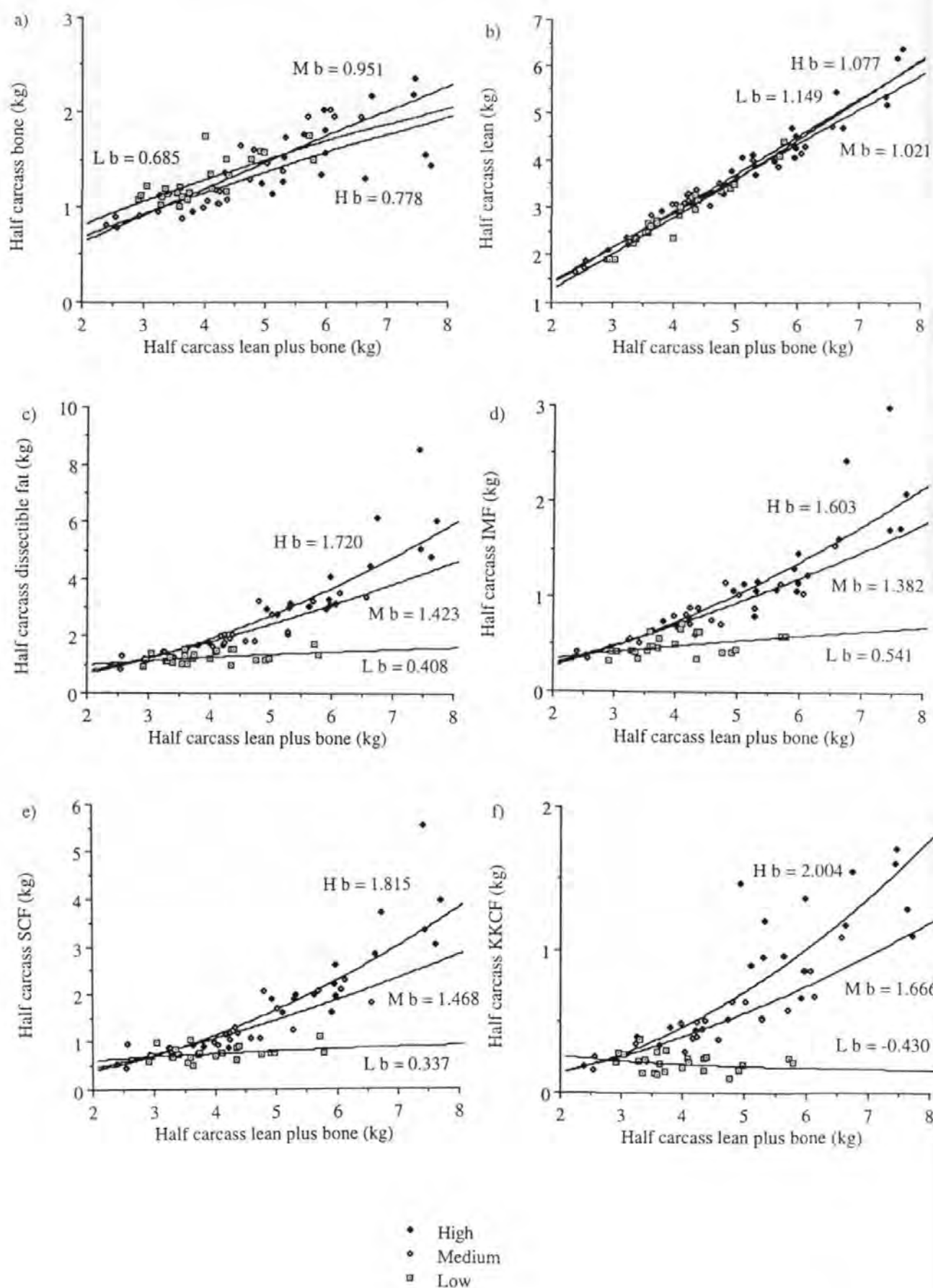
Figure 3.25

The effect of plane of nutrition on the allometric growth of half carcass tissues relative to the growth of half carcass lean plus bone

There was no significant effect of plane of nutrition on the growth rates of the fat-free shoulder, leg, chump or loin joints relative to half carcass lean plus bone (Table 3.18, Figure 3.26). However the relative growth rate of the fat-free breast was significantly greater in the L plane goats (b = 1.146) than in the M plane goats (b = 0.687), while the relative growth of the fat-free best end was significantly greater in the M plane goats (b = 1.202) than in the L plane goats (b = 0.850). The lack of any significant differences between the L and H planes of nutrition suggested that the differences between the L and M planes were attributable to causes other than a direct effect of plane of nutrition. The breast was a particularly difficult joint to dissect and it was likely that with the relatively large number of technicians involved in the dissections differences in individual dissection technique may have affected the result.
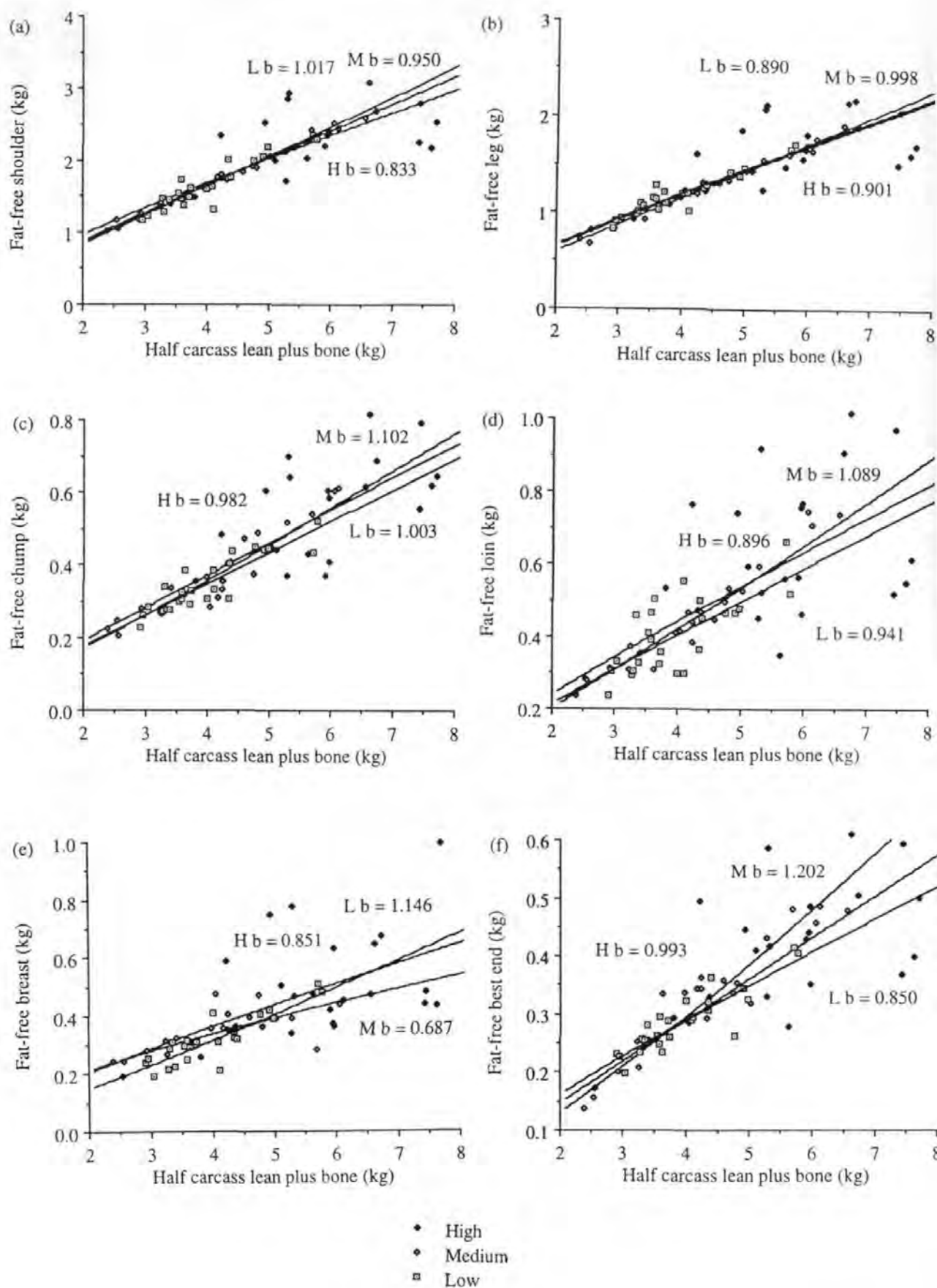
Figure 3.26

The effect of plane of nutrition on the allometric growth of the fat-free commercial carcass

joints relative to the growth of half carcass lean plus bone

3.3.9 The effect of plane of nutrition on the allometric growth of half carcass tissues within the carcass joints relative to the total weight of each tissue in the dissected half carcass

The differential development of each carcass tissue within the carcass joints relative to the growth of the total weight of that tissue in the dissected half carcass was examined for each plane of nutrition by means of linearised allometric equations (Appendix II). The equations were compared by covariance analysis to determine the effect of plane of nutrition on the differential development of each carcass tissue (Appendix II).

There was no significant effect of plane of nutrition on the differential development of bone, total carcass fat or IMF within the half carcass (Table 3.19). The development of lean in the shoulder joint relative to total half carcass lean was significantly greater in the **L** plane goats than in the **M** and **H** plane goats ($P < 0.05$) and the development of SCF in the best end relative to total SCF in the half carcass was significantly greater in the **M** plane goats than in the **H** plane goats ($P < 0.05$). In view of the lack of any other significant effects of plane of nutrition within these two carcass tissues it was likely that these significant differences were attributable to the variation in the range of total half carcass tissue weights of the three planes of nutrition. Therefore it was concluded that there was no significant effect of plane of nutrition on the differential development of the half carcass tissues within the carcass joints.

Carcass joint	Carcass tissue														
	Bone			Lean			Total dissectible fat			IMF			SCF		
	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L
Leg	0.954	0.843	0.791	0.986	1.009	0.889	0.950	0.966	1.013	0.620	0.602	1.080	1.031	1.064	1.140
Shoulder	0.959	1.039	0.959	0.938[a]	0.933[a]	1.104[b]	0.889	0.829	0.998	1.045	1.052	0.926	0.796	0.710	0.713
Chump	0.995	1.305	1.031	1.019	1.037	0.945	0.971	0.986	0.890	0.692	0.684	0.610	1.091	1.124	1.320
Breast	0.980	0.788	1.252	1.077	0.886	1.238	1.057	1.018	0.854	1.044	1.104	0.850	1.136	1.085	1.090
Loin	1.113	1.193	1.366	1.069	1.074	0.885	1.126	1.262	1.330	1.002	1.056	1.220	1.174	1.314	1.560
Best end	1.147	1.046	1.121	1.131	1.297	0.976	1.220	1.324	1.176	1.373	1.385	1.810	1.171[a]	1.348[b]	1.210[ab]

Within each carcass tissue means in the same row with different superscripts are significantly different (P < 0.05)

Table 3.19

Effect of plane of nutrition on the allometric coefficients (b) for the growth of half carcass tissues in each commercial joint relative to the growth of the total weight of each tissue in the dissected half carcass

3.3.10 Prediction of half carcass composition of British Angora wether goats (16 - 60kg EBW) from sample joint composition, weight of offal parts and linear carcass measurements

(i) Accuracy of sample joint composition for the prediction of half carcass composition

There was no significant effect of plane of nutrition on the differential development of any of the carcass tissues (Section 3.3.9). Therefore the linearised data from all three treatments was pooled to determine which joints were the most accurate predictors of half carcass composition. Initially simple correlations were made between the weight of each tissue in the dissected joint and the weight of the same tissue in the dissected half carcass (Table 3.20).

Carcass joint	Carcass tissue				
	Bone	Lean	Total fat	IMF	SCF
Leg	0.937	0.979	0.936	0.658	0.921
Shoulder	0.961	0.981	0.990	0.970	0.954
Chump	0.789	0.939	0.957	0.833	0.960
Breast	0.799	0.839	0.961	0.925	0.943
Loin	0.719	0.919	0.970	0.894	0.955
Best end	0.870	0.905	0.984	0.950	0.968

All correlations significant at 0.1%

Table 3.20

Correlation coefficients (r) between the weight of tissue in the dissected joint and the weight of the same tissue in the dissected half carcass (n = 66)

The shoulder joint was the best single predictor of all half carcass tissues except SCF, having correlation coefficients (r) exceeding 0.95 for each correlation. Its high degree of accuracy as a predictor was primarily due to the fact that it represented a high proportion of total half carcass weight. As such it was too time consuming and expensive to be used as a sample joint.

With the exclusion of the shoulder the leg was the best predictor of bone and of lean with r values of 0.937 and 0.979 for the two tissues respectively. The leg was the worst predictor of total carcass fat, IMF and SCF, but with r values of 0.936 and 0.921 for total dissectible fat and SCF respectively was still an acceptable predictor of those tissues. The poor correlation of IMF in the leg with total IMF in the half carcass (r = 0.658) was attributed to the low IMF content of the joint and to its early maturing nature which limited its ability to accurately reflect a late maturing tissue such as fat.

With the exclusion of the shoulder the best end was the most accurate predictor of total half carcass fat, IMF and SCF with r values of 0.984, 0.950 and 0.968 for the three depots respectively. It was also the best predictor of half carcass bone after the leg (r = 0.870). Although it ranked relatively low as a predictor of half carcass lean the best end had an acceptable correlation coefficient of 0.905.

Linear regression equations were formulated for the prediction of half carcass tissue weight from the weight of each tissue in the leg and the best end, singly or in combination in simple regressions, or combined in multiple regressions (Table 3.21). The most accurate predictions of bone and of lean in the half carcass were achieved with the pooled data from the leg and the best end in simple regression equations (Equations 3 and 6), no improvement in accuracy being obtained by using the data from the two joints separately in multiple regression equations. Conversely the most accurate predictions of total carcass fat, IMF and SCF were achieved through the combination of the two joints separately in multiple regression equations (Equations 12, 16 and 20).

Dependent variate (y)	Independent variate(s) (x₁)	(x₂)	Regression equation	R^2 (%)
Log_{10} bone in half carcass (g)	Log_{10} bone in leg (g)		1. $y = 0.586 + 1.01\,x_1$	87.5
	Log_{10} bone in best end (g)		2. $y = 1.66 + 0.709\,x_1$	75.3
	Log_{10} bone in leg + best end (g)		3. $y = 0.50 + 0.988\,x_1$	91.2
	Log_{10} bone in leg (g)	Log_{10} bone in best end (g)	4. $y = 0.752 + 0.722\,x_1 + 0.267\,x_2$	91.2
Log_{10} lean in half carcass (g)	Log_{10} lean in leg (g)		5. $y = 0.438 + 1.03\,x_1$	95.8
	Log_{10} lean in best end (g)		6. $y = 1.83 + 0.729\,x_1$	81.7
	Log_{10} lean in leg + best end (g)		7. $y = 0.409 + 1.01\,x_1$	97.8
	Log_{10} lean in leg (g)	Log_{10} lean in best end (g)	8. $y = 0.654 + 0.798\,x_1 + 0.211\,x_2$	97.7
Log_{10} total fat in half carcass (g)	Log_{10} total fat in leg (g)		9. $y = 0.620 + 1.08\,x_1$	87.4
	Log_{10} fat in best end (g)		10. $y = 1.38 + 0.817\,x_1$	96.7
	Log_{10} fat in leg + best end (g)		11. $y = 0.611 + 0.986\,x_1$	95.7
	Log_{10} fat in leg (g)	Log_{10} fat in best end (g)	12. $y = 1.16 + 0.239\,x_1 + 0.659\,x_2$	97.4
Log_{10} IMF in half carcass (g)	Log_{10} IMF in leg (g)		13. $y = 1.24 + 0.832\,x_1$	44.6
	Log_{10} IMF in best end (g)		14. $y = 1.67 + 0.626\,x_1$	90.5
	Log_{10} IMF in leg + best end (g)		15. $y = 0.882 + 0.888\,x_1$	87.1
	Log_{10} IMF in leg (g)	Log_{10} IMF in best end (g)	16. $y = 1.58 + 0.0744\,x_1 + 0.599\,x_2$	90.6
Log_{10} SCF in half carcass (g)	Log_{10} SCF in leg (g)		17. $y = 1.03 + 0.884\,x_1$	84.8
	Log_{10} SCF in best end (g)		18. $y = 1.33 + 0.817\,x_1$	93.3
	Log_{10} SCF in leg + best end (g)		19. $y = 0.728 + 0.927\,x_1$	94.9
	Log_{10} SCF in leg (g)	Log_{10} SCF in best end (g)	20. $y = 1.11 + 0.336\,x_1 + 0.559\,x_2$	96.3

Table 3.21

Linear regression equations for predicting the weight of half carcass tissue (y) from the weight of that tissue in the leg and the best end (x) used singly or in combination (n = 66)

(ii) Accuracy of carcass measurements and the weight of offal parts and selected muscles for the prediction of half carcass composition

Carcass measurements and the weights of various offal parts and selected muscles were correlated with the weights of the half carcass tissues, as appropriate, to determine whether these inexpensive measurements could be used as alternatives to sample joint dissection or to improve the accuracy of the dissection data when used in combination with it in multiple regression equations.

Since there was no significant effect of plane of nutrition on the allometric development of the fat-free body (Section 3.3.8) the data from all three planes of nutrition was pooled to provide 66 observations per correlation for the lean and bone evaluations (Tables 3.22 and 3.24 respectively). The significant effect of the L plane of nutrition on the development of KKCF with respect to total body fat, excluding visceral and mesenteric fat (Table 3.15), indicated that the internal fat depots would not accurately reflect carcass fat content in goats in which fat mobilisation had occurred. The L plane data was therefore excluded from the correlations of KKCF and omental fat against carcass dissectible fat (Table 3.26) resulting in only 42 observations per correlation for those tissues.

The variables having the highest correlations with the respective carcass tissues were used to formulate linear regression equations for the prediction of the weight of half carcass lean, bone, total dissectible fat, IMF and SCF (Tables 3.23, 3.25, 3.27, 3.28 and 3.29 respectively).

(a) Prediction of half carcass lean

The highest positive correlations with the weight of lean in the half carcass, excluding the weight of lean in the sample joints, were obtained with the circumference of the buttocks and the weight of the *L. dorsi* from the best end, with coefficients of 0.951 and 0.930 respectively (Table 3.22). The weight of the *L. dorsi* from the loin produced a poorer correlation of 0.843, which may have been due to the variable number of vertebral processes

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found in the loin joint. There was a high positive correlation of 0.878 between the weight of the four feet and the weight of lean in the half carcass. The feet were a useful predictor since their use necessitated no destruction of the carcass, but were limited in their predictive capability by their early maturity which probably affected their ability to reflect the weight of lean in the more mature carcasses. The same was true of the weight of the heart which had a relatively poor correlation with the weight of lean in the half carcass (0.760). This relationship may also have been affected by fat deposition in the organ in the heavier goats.

There was a moderate positive correlation of 0.805 between eye muscle area and half carcass lean but a poor negative correlation of -0.456 between the latter and the ratio A/B x 100, which was found to be a useful indicator of carcass lean in the sheep by Pálsson and Vergés (1952).

The circumference of the buttocks was the only carcass measurement to provide a satisfactory prediction of half carcass lean when used alone in a simple regression equation (Table 3.23, Equation 21) providing an R^2 value of 90.3%. It also improved the accuracy of prediction of the weight of lean in the leg from 95.8 to 96.1% (Equation 24), the best end from 81.7 to 94.8% (Equation 25) and both joints combined in a multiple regression from 97.7 to 97.9% (Equation 28).

The weight of *L. dorsi* in the best end provided a better estimate of half carcass lean (R^2 = 86.2%; Equation 22) than the total weight of lean in that joint (R^2 = 81.7%) since it avoided any errors associated with inaccurately split vertebrae or inadequate cleaning of the bones. In combination with other variables such as the circumference of the buttocks (Equation 23), the weight of lean in the leg (Equation 26) or both (Equation 28) it did not improve accuracy as much as the total weight of lean from the best end, but this may have been attributable to the fact that missing data reduced the number of observations from 66 to 61 for all equations incorporating the weight of the *L. dorsi*.

Variable	Correlation coefficient (r)	Significance	n
Log_{10} lean in leg (g)	0.979	***	66
Log_{10} lean in best end (g)	0.905	***	66
Log_{10} circumference of buttocks (mm)	0.951	***	66
Log_{10} *L. dorsi* in best end (g)	0.930	***	61
Log_{10} four feet (g)	0.878	***	66
Log_{10} side length (mm)	0.862	***	66
Log_{10} *L. dorsi* in loin (g)	0.843	***	64
Log_{10} eye muscle area (mm^2)	0.805	***	64
Log_{10} heart (g)	0.760	***	66
Log_{10} A/B x 100	-0.456	***	64

Table 3.22

Correlation coefficients (r) between log_{10} of some selected weights and measurements and log_{10} weight of lean tissue in the dissected half carcass (g)

Independent variates (x)	Regression equation	R^2 (%)
x_1 Log_{10} lean in leg (g)	5. $y = 0.438 + 1.03\,x_1$	95.8
x_1 Log_{10} lean in best end (g)	6. $y = 1.83 + 0.729\,x_1$	81.7
x_1 Log_{10} lean in leg (g) x_2 Log_{10} lean in best end (g)	8. $y = 0.654 + 0.798\,x_1 + 0.211\,x_2$	97.7
x_1 Log_{10} circumference of buttocks (mm)	21. $y = -4.12 + 2.81\,x_1$	90.3
x_1 Log_{10} $L.\ dorsi$ in best end (g)	22. $y = 1.96 + 0.806\,x_1$	86.2†
x_1 Log_{10} $L.\ dorsi$ in best end (g) x_2 Log_{10} circumference of buttocks (mm)	23. $y = -2.13 + 0.322\,x_1 + 1.85\,x_2$	93.1†
x_1 Log_{10} lean in leg (g) x_2 Log_{10} circumference of buttocks (mm)	24. $y = -0.507 + 0.844\,x_1 + 0.556\,x_2$	96.1
x_1 Log_{10} lean in best end (g) x_1 Log_{10} circumference of buttocks (mm)	25. $y = -2.32 + 0.304\,x_1 + 1.89\,x_2$	94.8
x_1 Log_{10} lean in leg (g) x_2 Log_{10} $L.\ dorsi$ in best end (g)	26. $y = 0.679 + 0.842\,x_1 + 0.17\,x_2$	96.4†
x_1 Log_{10} lean in leg (g) x_2 Log_{10} lean in best end (g) x_3 Log_{10} circumference of buttocks (mm)	27. $y = -0.091 + 0.657\,x_1 + 0.205\,x_2$ $+ 0.434\,x_3$	97.9
x_1 Log_{10} lean in leg (g) x_2 Log_{10} $L.\ dorsi$ in best end (g) x_3 Log_{10} circumference of buttocks (mm)	28. $y = -0.312 + 0.832\,x_1 + 0.033\,x_2$ $+ 0.470\,x_3$	96.5†

Table 3.23

Linear regression equations for predicting log_{10} weight of lean in the half carcass (y) from the weight of lean in the leg and the best end, offal weights, linear carcass measurements and the weight of the $L.\ dorsi$ from the best end (n = 66; † n = 61)

(b) Prediction of half carcass bone

The correlations between the various predictors and half carcass bone were generally lower than those for half carcass lean, ranging from 0.237 to 0.782 (Table 3.24). Most were significant at 0.1% but none of the coefficients were high enough to consider a linear measurement or offal part as a single predictor of half carcass bone. The F and F - T measurements (total and upper leg length respectively) were too severely affected by fat deposition in the crutch to be useful predictors of bone mass and the early maturing nature of the T measurement (lower leg length) affected its ability to reflect the weight of bone in the more mature carcasses. The later maturing measurements of side depth and chest width had greater r values of 0.630 and 0.725 respectively. These measurements may have been influenced by lean and fat development which would have reduced their ability to accurately reflect half carcass bone mass in the more mature carcasses. Excluding the weight of bone in the sample joints the highest correlation coefficient of 0.782 was achieved with the relatively late maturing side length which was unaffected by lean or fat deposition in the carcass.

The best combination of linear measurements and offal parts into a multiple regression equation incorporated side length, chest width and the weight of the four feet (Equation 29, Table 3.25). This combination of early and late maturing measurements was likely to be accurate over a wide range of carcass maturities but with an R^2 value of only 64.1% it was not an acceptable alternative to sample joint dissection (Equations 1, 2 and 4).

The accuracy of the leg alone as a sample joint was slightly improved from 87.5 to 88.6% by including the T measurement in the equation (Equation 30). The accuracy of the best end alone as a sample joint was substantially improved from 75.3 to 85.5% by including side length in the equation (Equation 31). The most accurate prediction of half carcass bone was achieved with the combination of the weights of bone from both sample joints in a multiple regression equation (Equation 4). The R^2 value of 91.2% was not increased by including any other measurements in the equation.

Variable	Correlation coefficient (r)	Significance	n
Log_{10} bone in leg (g)	0.937	***	66
Log_{10} bone in best end (g)	0.870	***	66
Log_{10} side length (mm)	0.782	***	66
Log_{10} length from femur fossa to 12th rib (mm)	0.777	***	66
Log_{10} four feet (g)	0.777	***	66
Log_{10} chest width (mm)	0.725	***	60
Log_{10} side depth (mm)	0.630	***	66
Log_{10} T (mm)	0.546	***	66
Log_{10} F (mm)	0.502	***	66
Log_{10} F -T (mm)	0.237	*	66

Table 3.24

Correlation coefficients (r) between log_{10} of some selected weights and measurements and log_{10} weight of bone in the dissected half carcass (g)

Independent variates (x)		Regression equation	R^2 (%)
x_1	Log_{10} bone in leg (g)	1. $y = 0.586 + 1.01\ x_1$	87.5
x_1	Log_{10} bone in best end (g)	2. $y = 1.66 + 0.709\ x_1$	75.3
x_1 x_2	Log_{10} bone in leg (g) Log_{10} bone in best end (g)	4. $y = 0.752 + 0.722\ x_1 + 0.267\ x_2$	91.2
x_1 x_2 x_3	Log_{10} side length (mm)† Log_{10} chest width (mm) Log_{10} weight of four feet (g)	29. $y = -1.70 + 1.08\ x_1 + 0.24\ x_2 + 0.444\ x_3$	64.1
x_1 x_2	Log_{10} bone in leg (g) Log_{10} T (mm)	30. $y = 1.43 + 1.11\ x_1 - 0.505\ x_2$	88.6
x_1 x_2	Log_{10} bone in best end (g) Log_{10} side length (mm)	31. $y = -1.71 + 0.510\ x_1 + 1.37\ x_2$	85.5

Table 3.25

Linear regression equations for predicting log_{10} weight of bone in the half carcass (y) from the weight of bone in the leg and the best end, offal weights and linear carcass measurements (n = 66; †n = 60)

(c) Prediction of total dissectible fat in the half carcass

With the exceptions of the C and D measurements for back fat thickness there were high positive correlations between all of the variables tested and total dissectible side fat (Table 3.26). The highest correlations were achieved with the weight of fat in the best end followed by the weight of fat in the leg, with r values of 0.984 and 0.936 respectively. The sample joints were therefore the best single predictors of total side fat (Equations 9 and 10, Table 3.27). The weights of KKCF and omental fat also had acceptable correlation coefficients of 0.928 and 0.920 respectively and therefore might be suitable predictors of total side fat when sample joint dissection is not desirable, provided it is known that fat mobilisation has not occurred (Equations 32 and 33). The accuracy of prediction of the individual fat depots was slightly increased by combining them both in a multiple regression (Equation 34).

The accuracy of the leg as a single sample joint for the prediction of total dissectible side fat was improved by including KKCF in the equation ($R^2 = 94.0\%$, Equation 35). There was no benefit from including a secondary measurement with the weight of fat in the best end. Furthermore the accuracy of this joint as a predictor of total side fat was only marginally improved from 96.7% to 97.4% by including the weight of fat in the leg in the equation (Equation 12).

The average back fat thickness [(C + D) / 2] produced a higher correlation coefficient with total side fat (0.790) than either the C or D measurement alone (0.763 and 0.746 respectively) but the relationship was not strong enough for the measurement to be used as a single predictor. When combined with total fat from the leg in a multiple regression it increased the accuracy of the leg as a predictor of total side fat from 87.4% (Equation 9) to 93.0% (Equation 36). Back fat thickness would therefore be a suitable secondary measurement to be used in conjunction with the weight of fat in the leg as an alternative to KKCF or in circumstances when it can not be guaranteed that internal fat mobilisation has not occurred.

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Variable	n	$\log_{10}$ total fat	$\log_{10}$ IMF	$\log_{10}$ SCF
$\log_{10}$ total fat in best end (g)	66	0.984***	0.953***	0.976***
$\log_{10}$ total fat in leg (g)	66	0.936***	0.921***	0.919***
$\log_{10}$ IMF in best end (g)	66		0.950***	0.845***
$\log_{10}$ IMF in leg (g)	66		0.658***	0.519***
$\log_{10}$ SCF in best end (g)	66		0.877***	0.968***
$\log_{10}$ SCF in leg (g)	66		0.870***	0.921***
$\log_{10}$ C (mm)	58	0.763***	0.719***	0.764***
$\log_{10}$ D (mm)	56	0.746***	0.723***	0.743***
$\log_{10}$ (C + D) / 2 (mm)	56	0.790***	0.749***	0.791***
$\log_{10}$ KKCF (g)†	42	0.928***	0.913***	0.917***
$\log_{10}$ omental fat (g)†	42	0.920***	0.889***	0.917***

†Excludes L plane data; ***significance of correlation coefficient

Table 3.26

Correlation coefficients (r) between $\log_{10}$ of some selected weights and measurements and $\log_{10}$ weight of total fat, IMF and SCF in the dissected half carcass (g)

Independent variates (x)	Regression equation	R^2 (%)
x_1 $\log_{10}$ total fat in leg (g)	9. $y = 0.620 + 1.08\, x_1$	87.4
x_1 $\log_{10}$ total fat in best end (g)	10. $y = 1.38 + 0.817\, x_1$	96.7
x_1 $\log_{10}$ total fat in leg (g) x_2 $\log_{10}$ total fat in best end (g)	12. $y = 1.16 + 0.239\, x_1 + 0.659\, x_2$	97.4
x_1 $\log_{10}$ KKCF (g)†	32. $y = 0.320 + 0.778\, x_1$	85.7
x_1 $\log_{10}$ omental fat (g)†	33. $y = 0.245 + 0.764\, x_1$	84.2
x_1 $\log_{10}$ KKCF (g) x_2 $\log_{10}$ omental fat (g)†	34. $y = 0.285 + 0.451\, x_1 + 0.347\, x_2$	87.7
x_1 $\log_{10}$ total fat in leg (g) x_2 $\log_{10}$ KKCF (g)†	35. $y = 1.58 + 0.703\, x_1 + 0.277\, x_2$	94.0
x_1 $\log_{10}$ total fat in leg (g) x_2 $\log_{10}$ [(C + D) / 2] (mm)‡	36. $y = 1.22 + 0.788\, x_1 + 0.251\, x_2$	93.0†

Table 3.27

Linear regression equations for predicting $\log_{10}$ weight of fat in the half carcass (y) from the weight of fat in the leg and the best end, offal weights and back fat thickness

(n = 66; †n = 42; ‡n = 56)

(d) Prediction of intermuscular fat in the half carcass

The best correlation of half carcass IMF with non-dissection data was achieved with KKCF, with an r value of 0.913 (Table 3.26). The corresponding prediction equation (Table 3.28, Equation 37) might provide an adequate prediction of half carcass IMF provided it is known that fat mobilisation has not occurred. Omental fat was a comparatively poor predictor of IMF (Equation 38) and did not improve the accuracy of KKCF when combined in a multiple regression equation (Equation 39). Back fat thickness correlated relatively poorly with half carcass IMF. The average value [(C + D) / 2] produced the highest correlation coefficient of the three measurements taken (0.749) but was of little use as a predictor of IMF either alone or in combination with the non-carcass fat data or dissection data.

The highest correlations with half carcass IMF were achieved with the weight of total fat in the best end, total fat in the leg and IMF in the best end, with r values of 0.953, 0.921 and 0.950 respectively (Table 3.26). The correlation between IMF in the leg and IMF in the half carcass was poor (0.658) due to the low weight of IMF in the leg joint in even the most mature carcasses.

The weight of total fat in the leg was the most accurate predictor of half carcass IMF when the leg was used as a single sample joint (Equation 40). The R^2 value of 84.7% was not improved by dividing the total fat into its separate depots for use either singly or combined in a multiple regression equation. However, using data obtained from the **H** and **M** plane goats only, a greater accuracy of prediction was obtained by including KKCF in the equation (Equation 41), increasing R^2 to 88.9%.

The best end was a better predictor of half carcass IMF than the leg. The total weight of fat in the best end gave a more accurate estimate of half carcass IMF than either of the separated fat depots used alone, with an R^2 value of 90.6% (Equation 42) but the accuracy of this equation was increased to 94.7% by combining the weights of the separated fat depots in a multiple regression equation (Equation 43). Neither equation was improved by including the weight

of KKCF.

The weights of total fat from both sample joints produced a small improvement in the accuracy of prediction to 91.9% (Equation 44) over the use of total fat from the best end alone. Accuracy was further increased to 95.1% when the separated fat depots from each joint were incorporated into a multiple regression equation (Equation 45).

Independent variates (x)	Regression equation	R^2 (%)
x_1 Log_{10} KKCF (g)†	37. $y = -0.084 + 0.706\ x_1$	82.9
x_1 Log_{10} omental fat (g)†	38. $y = -0.150 + 0.682\ x_1$	78.6
x_1 Log_{10} KKCF (g) x_2 Log_{10} omental fat (g)†	39. $y = -0.106 + 0.497\ x_1 + 0.222\ x_2$	83.6
x_1 Log_{10} total fat in leg (g)	40. $y = 0.352 + 1.02\ x_1$	84.7
x_1 Log_{10} total fat in leg (g) x_1 Log_{10} KKCF (g)†	41. $y = -1.47 + 0.560\ x_1 + 0.307\ x_2$	88.9
x_1 Log_{10} total fat in best end (g)	42. $y = 1.10 + 0.761\ x_1$	90.6
x_1 Log_{10} IMF in best end (g) x_2 Log_{10} SCF in best end (g)	43. $y = 1.44 + 0.446\ x_1 + 0.275\ x_2$	94.7
x_1 Log_{10} total fat in best end (g) x_2 Log_{10} total fat in leg (g)	44. $y = 0.794 + 0.543\ x_1 + 0.330\ x_2$	91.9
x_1 Log_{10} IMF in best end (g) x_2 Log_{10} SCF in best end (g) x_3 Log_{10} IMF in leg (g) x_4 Log_{10} SCF in leg (g)	45. $y = 1.27 + 0.393\ x_1 + 0.212\ x_2 + 0.069\ x_3$ $+ 0.119\ x_4$	95.1

Table 3.28

Linear regression equations for predicting log_{10} weight of IMF in the half carcass (y) from the weight of IMF in the leg and the best end, offal weights and linear carcass measurements
(n = 66; †n = 42)

(e) Prediction of subcutaneous fat in the half carcass

The weights of KKCF and omental fat and average backfat thickness had higher positive correlations with half carcass SCF than with IMF, having r values of 0.900, 0.907 and 0.791 respectively (Table 3.26). KKCF and omental fat produced reasonably accurate regression equations when used alone or combined in a multiple regression equation when the L plane data was excluded from the analysis (Table 3.29, Equations 46, 47 and 48). The relationship between back fat thickness and half carcass SCF was not strong enough for the former to be used as a single predictor (r = 0.791) but it was effective in increasing the accuracy of prediction of KKCF to 85.9% (Equation 49).

Total fat in the best end and SCF in the best end produced the highest correlations with half carcass SCF, with r values of 0.976 and 0.968 respectively. Correlation of half carcass SCF with total fat or SCF in the leg also produced high correlation coefficients (0.919 and 0.921 respectively) and thus either sample joint could be used as a single predictor of SCF.

The best estimate of half carcass SCF using the leg alone was achieved using the total weight of fat in the leg (Equation 50). The R^2 value of 84.1% was not significantly improved by dividing the fat into its constituent depots for use in a multiple regression equation, but the inclusion of KKCF or average back fat thickness increased R^2 to 92.9% and 90.1% respectively (Equations 51 and 52).

Greater accuracy was achieved using the best end rather than the leg as a single sample joint. Regression of total fat in the best end on half carcass SCF produced an R^2 value of 95.2% (Equation 53) which was increased slightly to 95.6% by the separation of the fat into its constituent depots (Equation 54). The accuracy of the best end as a single sample joint was not increased by including KKCF or back fat thickness in either equation.

The most accurate estimate of half carcass SCF was obtained using the weights of the separated fat depots from both sample joints in a multiple regression equation which had an

R^2 value of 97.5% (Equation 55). Total weight of fat from the leg and the best end provided no better estimate of half carcass SCF than total fat from the best end alone (Equation 56).

Independent variates (x)	Regression equation	R^2 (%)
x_1 Log_{10} KKCF (g)†	46. $y = 0.098 + 0.830\ x_1$	83.6
x_1 Log_{10} omental fat (g)†	47. $y = 0.017 + 0.823\ x_1$	83.8
x_1 Log_{10} KKCF (g) x_2 Log_{10} omental fat (g)†	48. $y = 0.055 + 0.425\ x_1 + 0.430\ x_2$	86.3
x_1 Log_{10} KKCF (g) x_2 Log_{10} [(C + D) / 2] (mm)#	49. $y = -0.05 + 0.688\ x_1 + 0.240\ x_2$	85.9
x_1 Log_{10} total fat in leg (g)	50. $y = 0.296 + 1.12\ x_1$	84.1
x_1 Log_{10} total fat in leg (g) x_1 Log_{10} KKCF (g)†	51. $y = -1.88 + 0.803\ x_1 + 0.258\ x_2$	92.9
x_1 Log_{10} total fat in leg (g) x_2 Log_{10} [(C + D) / 2] (mm)‡	52. $y = 0.974 + 0.790\ x_1 + 0.284\ x_2$	90.1
x_1 Log_{10} total fat in best end (g)	53. $y = 1.06 + 0.858\ x_1$	95.2
x_1 Log_{10} SCF in best end (g) x_1 Log_{10} IMF in best end (g)	54. $y = 1.30 + 0.686\ x_1 + 0.166\ x_2$	95.6
x_1 Log_{10} IMF in best end (g) x_2 Log_{10} SCF in best end (g) x_3 Log_{10} IMF in leg (g) x_4 Log_{10} SCF in leg (g)	55. $y = 1.23 + 0.132\ x_1 + 0.547\ x_2 - 0.097\ x_3$ $+ 0.265\ x_4$	97.5
x_1 Log_{10} total fat in best end (g) x_2 Log_{10} total fat in leg (g)	56. $y = 0.900 + 0.742\ x_1 + 0.175\ x_2$	95.4

Table 3.29

Linear regression equations for predicting log_{10} weight of SCF in the half carcass (y) from the weight of SCF in the leg and the best end, offal weights and linear carcass measurements

(n = 66; †n = 42; ‡n = 56; #n = 34)

(iii) Statistical evaluation of the proposed prediction equations

The prediction equations were grouped according to the conditions under which each would be expected to be used, as follows;

1. The use of offal parts and carcass measurements only to avoid destruction of the carcass;

2. Dissection of the leg alone as the easiest sample joint to remove with minimal damage to the carcass and the best predictor of half carcass lean and bone;

3. Dissection of the best end alone as the most accurate predictor of half carcass fat;

4. Dissection of both the leg and the best end to provide the most accurate prediction possible of all half carcass tissues.

Within each group the most practical equations with the highest R^2 values for the prediction of each carcass tissue were tested for their accuracy of prediction (Tables 3.30 to 3.33). A separate population of 23 Texan x New Zealand Angora wether goats, of mean empty body weight 25.2 ± 3.2kg, was slaughtered and half carcass dissections performed in the course of Trial 2. The half carcass composition of these goats was then estimated from their sample joint data, offal parts and carcass measurements using the proposed prediction equations. The predicted and actual values for the weight of each carcass tissue were compared using analysis of variance and the correlation coefficients between the two sets of values were determined.

(a) The use of offal parts and carcass measurements

The use of offal parts and carcass measurements for the prediction of carcass composition was less satisfactory than the use of corresponding equations incorporating sample joint dissection data (Table 3.30). The R^2 values were generally less than 90% although the correlations between actual and predicted values were significant ($P < 0.01$) for every equation tested. The values of half carcass lean predicted with Equation 21 were not significantly different from the actual values in the test population, indicating the suitability of this equation for prediction in the absence of dissection data. Similarly the actual bone values

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were not significantly different from the values predicted with Equation 29, but the poor correlation of actual and predicted bone values (0.513) reflected the high variability in the bone data with which the equation was formulated and in the test population. (NB the original Equation 29 given in Table 3.25 was substituted here for one which did not include the weight of the feet, since that measurement was not recorded in the test population and could not therefore be tested. It is possible that the inclusion of the feet in the equation would increase its accuracy of prediction).

All of the proposed equations for the prediction of half carcass fat, IMF and SCF from the weight of the internal fat depots predicted fat values which were significantly lower than the actual values ($P < 0.001$). This confirmed that the relationship between the internal fat depots and carcass fat was variable and influenced by plane of nutrition. Neither KKCF nor omental fat was therefore suitable for the prediction of carcass fat, either alone or in combination with dissection data and there was no acceptable alternative to sample joint dissection for the prediction of half carcass fat content.

Dependent variate (y)	Independent variates (x)	Regression equation	R^2 (%)	Sig[a]	r[b]
Log_{10} lean (g)	x_1 Log_{10} circumference of buttocks (mm)	21. $y = -4.12 + 2.81\, x_1$	90.3	NS	0.934**
Log_{10} bone (g)	x_1 Log_{10} side length (mm) x_2 Log_{10} chest width (mm)[†]	29. $y = -2.81 + 1.86\, x_1 + 0.344\, x_2$	61.7	NS	0.513**
Log_{10} total dissectible fat (g)	x_1 Log_{10} KKCF (g)[‡]	32. $y = 0.320 + 0.778\, x_1$	85.7	***	0.921**
	x_1 Log_{10} omental fat (g)[‡]	33. $y = 0.245 + 0.764\, x_1$	84.2	***	0.709**
	x_1 Log_{10} KKCF (g) x_2 Log_{10} omental fat (g)[‡]	34. $y = 0.285 + 0.451\, x_1 + 0.347\, x_2$	87.7	***	0.879**
Log_{10} IMF (g)	x_1 Log_{10} KKCF (g)[‡]	37. $y = -0.084 + 0.706\, x_1$	82.9	***	0.896**
Log_{10} SCF (g)	x_1 Log_{10} KKCF (g)[‡]	46. $y = 0.098 + 0.830\, x_1$	83.6	***	0.922**
	x_1 Log_{10} omental fat (g)[‡]	47. $y = 0.017 + 0.823\, x_1$	83.8	***	0.689**
	x_1 Log_{10} KKCF (g) x_2 Log_{10} omental fat (g)[‡]	48. $y = 0.055 + 0.425\, x_1 + 0.430\, x_2$	86.3	***	0.851**

[†]n = 60; [‡]n = 42;

[a]Significance of difference between predicted and actual values (n = 23);

[b]Correlation between predicted and actual values and significance (n = 23)

Table 3.30

Linear regression equations for predicting the weight of half carcass tissues (y) from the weights of selected offal parts and carcass measurements

(b) The leg as a single sample joint

The use of the leg as a single sample joint provided suitable prediction equations for most carcass tissues (Table 3.31). The prediction of half carcass lean from the weight of lean in the leg and the circumference of the buttocks (Equation 24) yielded values which were not significantly different from the actual values, but the difference between the actual bone weights and those predicted from the weight of bone in the leg plus the T measurement (Equation 30) was significant ($P < 0.05$). A paired t-test showed that the estimated values were consistently lower than the actual values ($P < 0.001$). Re-examination of the raw data from the test population revealed that no waste was recorded for the leg joint, which suggested that the ligaments and tendons were weighed as bone. This was not true of the carcasses from which the equation was formulated. The inadequacy of the prediction was therefore attributable to error in the dissection of the test population and not to the inaccuracy of the equation, which would probably yield accurate predictions provided the dissection technique of the sample joint was consistent with that used to generate the original data used to formulate the equation.

When used alone in simple regression equations the total weight of fat in the leg provided accurate estimates of total carcass fat, IMF and SCF (Equations 9, 40 and 50 respectively). When the weight of KKCF was included in the equations R^2 was significantly increased (Equations 35, 41 and 51) and the correlations between the actual and predicted values were improved, but the predicted values were significantly lower than the actual values for all three equations incorporating KKCF ($P < 0.001$), confirming that the internal fat depot was not a suitable predictor of carcass fat. Substitution of mean back fat thickness [(C + D) / 2] for KKCF produced equations for the prediction of total fat and SCF in the half carcass with comparable R^2 values (Equations 36 and 52, Tables 3.27 and 3.29 respectively) but since this measurement was not recorded in the test population it was not possible to test the equations which included it. The best estimates of total fat, IMF and SCF in the half carcass were therefore given by the weight of fat in the leg alone.

Dependent variate (y)	Independent variates (x)	Regression equation	R^2 (%)	Sig[a]	r[b]
Log_{10} lean (g)	x_1 Log_{10} lean in leg (g) x_2 Log_{10} circumference of buttocks (mm)	24. $y = -0.507 + 0.844\ x_1 + 0.556\ x_2$	96.1	NS	0.960**
Log_{10} bone (g)	x_1 Log_{10} bone in leg (g) x_2 Log_{10} T (mm)	30. $y = 1.43 + 1.11\ x_1 - 0.505\ x_2$	88.6	*	0.680**
Log_{10} total dissectible fat (g)	x_1 Log_{10} total fat in leg (g)	9. $y = 0.620 + 1.08\ x_1$	87.4	NS	0.942**
	x_1 Log_{10} total fat in leg (g) x_2 Log_{10} KKCF (g)‡	35. $y = 1.58 + 0.703\ x_1 + 0.277\ x_2$	94.0	***	0.958**
Log_{10} IMF (g)	x_1 Log_{10} total fat in leg (g)	40. $y = 0.352 + 1.02\ x_1$	84.7	NS	0.907**
	x_1 Log_{10} total fat in leg (g) x_2 Log_{10} KKCF (g)‡	41. $y = -1.47 + 0.560\ x_1 + 0.307\ x_2$	88.9	***	0.927**
Log_{10} SCF (g)	x_1 Log_{10} total fat in leg (g)	50. $y = 0.296 + 1.12\ x_1$	84.1	NS	0.949**
	x_1 Log_{10} total fat in leg (g) x_2 Log_{10} KKCF (g)‡	51. $y = -1.88 + 0.803\ x_1 + 0.258\ x_2$	92.9	***	0.963**

‡n = 42;

[a]Significance of difference between predicted and actual values (n = 23);

[b]Correlation between predicted and actual values and significance (n = 23)

Table 3.31

Linear regression equations for predicting the weight of half carcass tissues (y) from the weights of tissues in the dissected leg, selected offal parts and carcass measurements

(c) The best end as a single sample joint

Compared with the leg, the best end was a more useful single sample joint for the prediction of all carcass tissues (Table 3.32). Equations for the prediction of total fat, IMF and SCF had R^2 values of 96.7, 94.7 and 95.6% (Equations 10, 43 and 54 respectively) compared with poorer values of 87.4, 84.7 and 84.1% for equivalent equations incorporating the leg dissection data (Equations 9, 40 and 50 respectively). Furthermore the equations for the prediction of lean and bone were only slightly less accurate when the best end was used instead of the leg. R^2 values for the prediction of half carcass lean were 94.8 and 96.1% for the best end and the leg respectively (Equations 25 and 24), and 85.5 and 88.6% for the prediction of half carcass bone from the two joints respectively (Equations 31 and 30). All of the equations involving best end dissection data provided estimates of carcass tissue content which were not significantly different from the actual values. The correlations of actual and predicted values were greater than 0.96 with the exception of Equation 31 for the prediction of half carcass bone (r = 0.632). Although still significant at 1% this emphasised the high degree of error variation in the original data and in that of the test population, due to the difficulty in accurately splitting the vertebral processes.

(d) The leg and the best end combined

The accuracy of prediction of all carcass tissues was increased by incorporating dissection data from both sample joints into multiple regression equations (Table 3.33) all of which provided estimates of carcass tissue content which were not significantly different from the actual values.

Dependent variate (y)	Independent variates (x)	Regression equation	R^2 (%)	Sig[a]	r[b]
Log_{10} lean (g)	x_1 Log_{10} lean in best end (g) x_2 Log_{10} circumference of buttocks (mm)	25. $\quad y = -2.32 + 0.304\, x_1 + 1.89\, x_2$	94.8	NS	0.964**
Log_{10} bone (g)	x_1 Log_{10} bone in best end (g) x_2 Log_{10} side length (mm)	31. $\quad y = -1.71 + 0.510\, x_1 + 1.37\, x_2$	85.5	NS	0.632**
Log_{10} total dissectible fat (g)	x_1 Log_{10} total fat in best end (g)	10. $\quad y = 1.38 + 0.817\, x_1$	96.7	NS	0.984**
Log_{10} IMF (g)	x_1 Log_{10} IMF in best end (g) x_2 Log_{10} SCF in best end (g)	43. $\quad y = 1.44 + 0.446\, x_1 + 0.275\, x_2$	94.7	NS	0.971**
Log_{10} SCF (g)	x_1 Log_{10} SCF in best end (g) x_2 Log_{10} IMF in best end (g)	54. $\quad y = 1.30 + 0.686\, x_1 + 0.166\, x2$	95.6	NS	0.976**

[a]Significance of difference between predicted and actual values;

[b]Correlation between predicted and actual values and significance (n = 23)

Table 3.32

Linear regression equations for predicting the weight of half carcass tissues (y) from the weights of tissues in the dissected best end and selected carcass measurements

Dependent variate (y)	Independent variates (x)	Regression equation	R^2 (%)	Sig[a]	r[b]
Log_{10} lean (g)	x_1 Log_{10} lean in leg (g) x_2 Log_{10} lean in best end (g)	8. $\quad y = 0.654 + 0.798\, x_1 + 0.211\, x_2$	97.7	NS	0.975**
Log_{10} bone (g)	x_1 Log_{10} bone in leg (g) x_2 Log_{10} bone in best end (g)	4. $\quad y = 0.752 + 0.722\, x_1 + 0.267\, x_2$	91.2	NS	0.778**
Log_{10} total dissectible fat (g)	x_1 Log_{10} total fat in leg (g) x_2 Log_{10} total fat in best end (g)	12. $\quad y = 1.16 + 0.239\, x_1 + 0.659\, x_2$	97.4	NS	0.990**
Log_{10} IMF (g)	x_1 Log_{10} IMF in best end (g) x_2 Log_{10} SCF in best end (g) x_3 Log_{10} IMF in leg (g) x_4 Log_{10} SCF in leg (g)	45. $\quad y = 1.27 + 0.393\, x_1 + 0.212\, x_2$ $\quad\quad\quad + 0.069\, x_3 + 0.119\, x_4$	95.1	NS	0.976**
Log_{10} SCF (g)	x_1 Log_{10} IMF in best end (g) x_2 Log_{10} SCF in best end (g) x_3 Log_{10} IMF in leg (g) x_4 Log_{10} SCF in leg (g)	55. $\quad y = 1.23 + 0.132\, x_1 + 0.547\, x_2$ $\quad\quad\quad - 0.097\, x_3 + 0.265\, x_4$	97.5	NS	0.982**

[a]Significance of difference between predicted and actual values;

[b]Correlation between predicted and actual values and significance (n = 23)

Table 3.33

Linear regression equations for predicting the weight of half carcass tissues (y) from the weights of tissues in the dissected leg and best end

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3.3.11 Fibre production in the British Angora wether goat

(i) The effect of age and plane of nutrition on fleece weight and fibre quality

The mean fleece weight, staple length and fibre diameter for each treatment group at each sampling are presented in Appendix III. Since the shearing intervals were not equal the mass of fleece and the length of fibre produced per six month period were also calculated as a daily rate of production for the comparison of age groups within each plane of nutrition.

For each fibre characteristic measured a one way analysis of variance was performed between treatment groups at each age, within each plane of nutrition, to determine whether any trends caused by variation in age or plane of nutrition could be adequately described using only the data from the slaughter groups. There were no significant differences between treatment groups within each comparison with the exception of fibre diameter in the L plane goats at 18 months of age (Appendix III). Treatment group 18L had a significantly greater mean fibre diameter than treatment group 24L (25.11 and 21.97μm respectively, $P < 0.05$).

Despite the lack of significant differences the fibre data was very variable and the use of the slaughter groups to demonstrate age effects on fibre yield and quality resulted in misleading trends, particularly within the older animals. The effects of age and plane of nutrition on fibre yield and quality were therefore examined only within treatment groups 24H, 24M and 24L. With the exception of the latter, which was not sampled at six or nine months of age, these three treatment groups were sampled at every age throughout the trial and therefore provided a continuous set of data with which to monitor age changes. The data for each fibre characteristic were analysed using a two way analysis of variance (Table 3.34).

(a) Fleece growth rate

There was insufficient fleece weight and staple length data from the L plane goats to perform any statistical analysis of the effects of age on these two variables, or to examine the relationship between fibre yield and quality under the L plane of nutrition (section ii).

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There was a significant effect of age (P < 0.001), plane of nutrition (P < 0.05) and their interaction (P < 0.05) on the fleece growth rate of the **H** and **M** plane goats (Table 3.34). Daily fibre production increased with each age increase overall up to 18 months and then remained constant. Average daily production from birth to 24 months of age was significantly greater on the **H** plane (11.29g/day) than the **M** plane of nutrition (9.95g/day).

In the **M** plane goats there was a significant increase in the rate of fibre production from 5.83g/day between birth and six months to 14.84g/day between 12 and 18 months of age and a significant decrease to 10.57g/day between 18 and 24 months of age (P < 0.05). In the **H** plane goats daily fibre production increased significantly from 5.08g/day between birth and six months to 14.39g/day between 12 and 18 months (P < 0.05) but remained constant up to 24 months of age (Figure 3.27a).

Plane of nutrition	Age (months)	Fleece growth rate (g/day)	Fibre diameter (μm)	Increase in length (mm/day)
High	6	5.08a	18.97	0.86
	9		21.88	0.97
	12	11.04b	24.82	0.77
	15		27.56	0.89
	18	14.39cd	27.79	0.81
	21		29.84	0.81
	24	14.63d	27.09	0.59†
	Mean	11.29	25.42	0.81
Medium	6	5.83a	21.58	0.95
	9		20.80	0.95
	12	8.56ab	21.74	0.78‡
	15		24.50	0.92
	18	14.84d	23.43	0.73†
	21		26.77	0.79
	24	10.57bc	26.09	0.61‡
	Mean	9.95	23.56	0.82
s.e.		0.301	0.294	0.01
Significance of effect of				
	Age	***	***	***
	Plane of nutrition	*	**	NS
	Interaction	*	NS	NS

Means in each column with different superscripts are significantly different (P < 0.05); n = 6; †n = 4; ‡n = 5

Table 3.34

The effect of age on fleece growth rate, fibre diameter and increase in staple length of Angora wether goats reared on a high or medium plane of nutrition from six months to two years of age
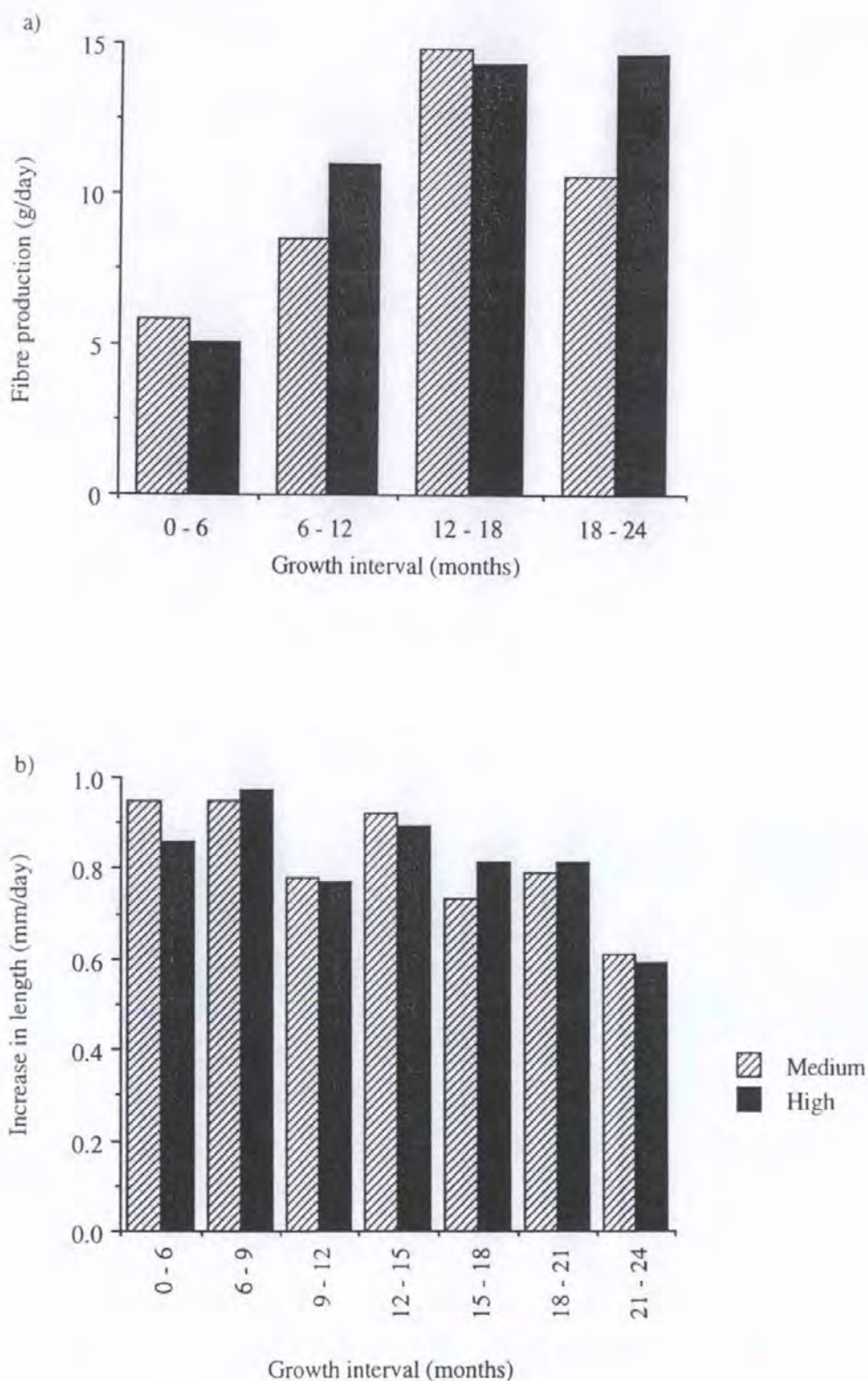
Figure 3.27

The effect of age on the mean daily fibre production and length growth rate of Angora wether goats reared from six to 24 months of age on a high or medium plane of nutrition

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(b) Increase in length

There was a significant effect of age on the daily increase in staple length of the combined **H** and **M** goats (P < 0.001, Table 3.34) with a downwards trend in both treatments from approximately 0.9mm/day between birth and six months to 0.6mm/day between 21 and 24 months of age (Figure 3.27b). This pattern of decrease strongly reflected the decline in dry matter intake throughout the trial of the goats on both planes of nutrition (Figure 3.3). It was possible that the decline in feed intake with age, rather than age *per se*, was the cause of the decrease in fibre growth rate but there was no significant effect of plane of nutrition on the daily increase in staple length. The average increase in length from birth to 24 months of age was 0.81mm/day for the **H** plane goats and 0.82g/day for the **M** plane goats (Table 3.34).

A distinct fluctuation was apparent in the length growth rate within each shearing interval (6-12 months, 12-18 months, 18-24 months) for both planes of nutrition. Fibre length increased more rapidly in the three months immediately after shearing than in the three months preceding the next shear (Figure 3.27b). Again this fluctuating pattern reflected the variation in feed intake within each shearing interval (Figure 3.3).

(c) Fibre diameter

There was a significant effect of age (P < 0.001) and plane of nutrition (P < 0.01) on the mean fibre diameter of the **H** and **M** plane goats (Table 3.34). The average diameter from six months to two years of age was greater on the **H** plane (25.42μm) than the **M** plane of nutrition (23.56μm). Fibre diameter increased with age up to 21 months and decreased between 21 and 24 months of age (Figure 3.28). The decrease was more marked in the **H** plane goats and coincided with the sudden rapid decline in feed intake of the *ad lib* goats during the last three months of the experiment (Figure 3.3).
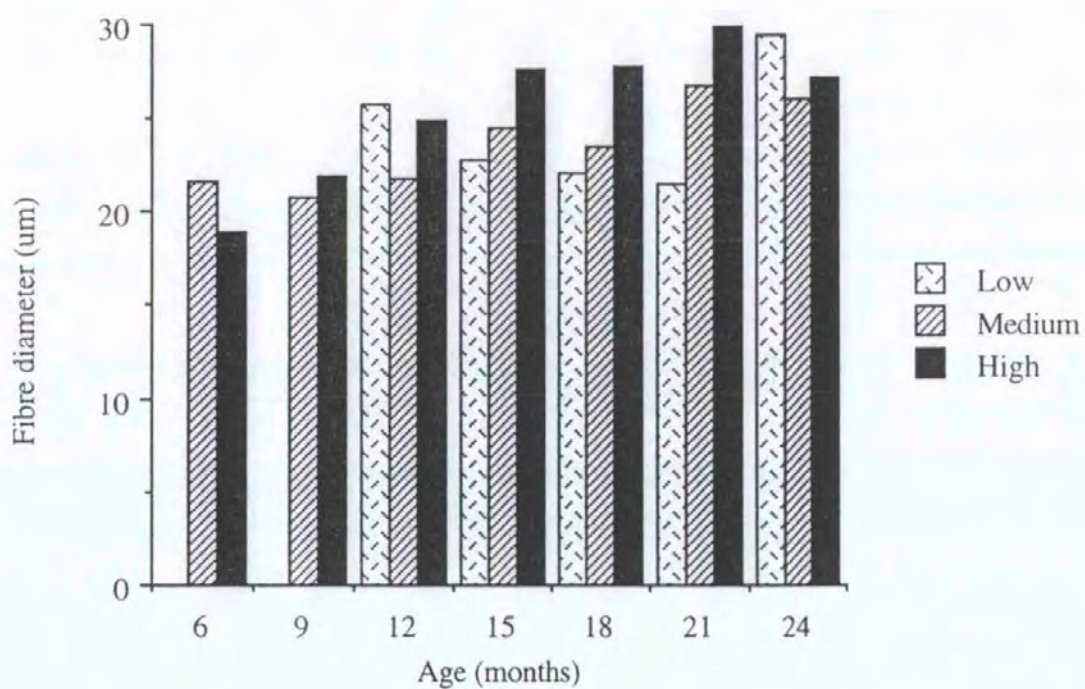
Figure 3.28

The effect of age on the mean fibre diameter of Angora wether goats reared from six to 24 months of age on a high, medium or low plane of nutrition

The effect of the **L** plane of nutrition on the changes in mean fibre diameter with age compared with the **M** and **H** planes was examined using two way analysis of variance of the data from all three planes of nutrition from 12 to 24 months of age since the treatment group 24L was not represented at six or nine months of age (Appendix III). There was a significant effect of age ($P < 0.01$), plane of nutrition ($P < 0.001$) and their interaction ($P < 0.01$) on mean fibre diameter (Table 3.35).

Fibre diameter increased with increasing plane of nutrition from 24.26μm in the **L** plane goats to 27.42μm in the **H** plane goats and with increasing age from approximately 24μm at 12 months to 27μm at 24 months of age. However the **L** plane followed an opposite trend with age to both the **M** and **H** planes. Fibre diameter decreased from 25.74μm at 12 months to 21.43μm at 21 months of age and then increased to 29.41μm at 24 months of age (Figure 3.28). Consequently between 15 and 21 months of age fibre diameter increased with increasing plane of nutrition and the difference between the **L** plane (21.43μm) and the **H** plane (29.84μm) was significant at 21 months of age ($P < 0.05$). At 24 months of age the large increase in fibre diameter of the **L** plane goats and the slight decrease in both the **M** and **H** plane goats to values of 29.41, 26.09 and 27.09μm respectively removed this trend (Table 3.35).

At 12 months of age the fibre diameter of the **L** plane goats was greater than that of either the **M** or the **H** plane goats, with values of 25.74, 21.74 and 24.82μm for the three planes respectively, but the differences were not significant.

| Age | Plane of nutrition | | |
(months)	High	Medium	Low
12	24.82abcd	21.74ab	25.74abcd
15	27.56bcd	24.50abcd	22.74ab
18	27.79bcd	23.43abc	21.97ab
21	29.84d	26.77abcd	21.43a
24	27.09abcd	26.09abcd	29.41cd
Mean	27.42	24.51	24.26
s.e.		0.316	
Significance of effect of			
Age		**	
Plane of nutrition		***	
Interaction		**	

Means with different superscripts are significantly different (P < 0.05); n = 6

Table 3.35

The effect of age on the mean fibre diameter (μm) of Angora wether goats reared on a high, medium or low plane of nutrition from six months to two years of age

(ii) The effect of a high or medium plane of nutrition on the relationship between fibre quality and the mass of fibre produced

The pattern of changes in the mass of fibre produced per day, the length of fibre produced per day and fibre diameter at shearing in the **H** and **M** plane goats from six months to two years of age are presented as the proportional increase or decrease over the value at six months of age for comparison (Figure 3.29). The sharp decrease in the mass of fibre produced per day by the **M** plane goats between 18 and 24 months of age, and the decrease in the daily elongation rate and fibre diameter of both planes of nutrition between the same ages suggested that any relationship between the mass of fibre produced and its quality may have been affected by the decline in feed intake of groups 24H and 24M between 21 and 24 months of age (Figure 3.3). The data for these two treatment groups at 24 months of age was therefore excluded from further analysis. The data recorded for groups 24H and 24M at six, 12 and 18 months was used to determine the relationships between the mass of fleece

produced at each shear and fibre length and diameter, and the effect of a **H** or **M** plane of nutrition on these relationships.

There was a non-significant positive correlation (r = 0.194) between $\log_{10}$ fleece growth rate and $\log_{10}$ increase in fibre length on the **H** plane of nutrition between six and 18 months of age (Table 3.36). There was a non-significant negative correlation (r = -0.183) between the two variables on the **M** plane of nutrition and when the data from both planes of nutrition was combined the resultant r value of 0.022 was also not significant. The increase in fleece growth rate with increasing age up to 18 months (Figure 3.29) was therefore not significantly related to variation in the fibre elongation rate.

Plane of nutrition	Correlation coefficient	n	Significance
High	0.194	18	NS
Medium	-0.183	15	NS
Combined	0.022	33	NS

Table 3.36

Correlation coefficients between $\log_{10}$ fleece growth rate (g/day) and $\log_{10}$ increase in fibre length (mm/day) of Angora wether goats reared from six to 18 months of age on a high or medium plane of nutrition

a) High plane

b) Medium plane

Diameter (um)
Length (mm/day)
Mass (g/day)
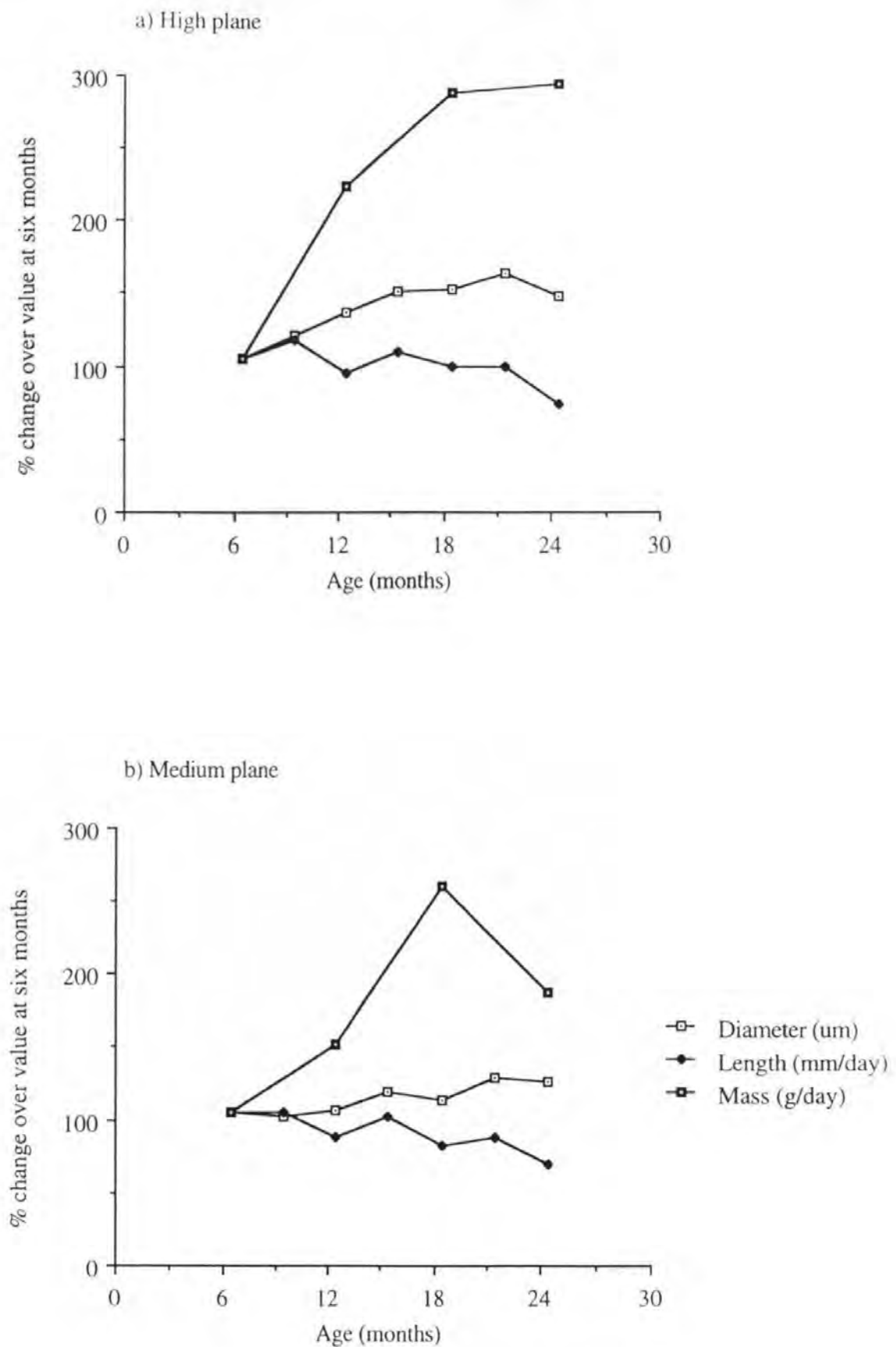
Figure 3.29

The effect of age on the mass and length of fleece produced per day and the mean fibre diameter at shearing of Angora wether goats reared from six to 24 months of age on a high or medium plane of nutrition

The correlation of $\log_{10}$ cumulative fleece weight against $\log_{10}$ fibre diameter resulted in an r value of 0.807 for the **H** plane of nutrition which was significant at 0.1% and a value of 0.374 for the **M** plane of nutrition which was not significant (Table 3.37). The value for the **M** plane was lower due to the more narrow range of values for fibre diameter compared with the **H** plane (Figure 3.30) which resulted in a greater proportion of the total variation attributable to residual variation than to treatment variation on the lower plane of nutrition. Consequently the regression of $\log_{10}$ **M** cumulative fleece weight onto $\log_{10}$ **M** fibre diameter produced a regression equation (Equation 58) which was a non-significant representation of the data.

Plane of nutrition	Correlation coefficient	n	Significance
High	0.807	18	***
Medium	0.374	18	NS
Combined	0.641	36	***

Table 3.37

Correlation coefficients between $\log_{10}$ cumulative fleece weight (kg) and $\log_{10}$ fibre diameter (μm) of Angora wether goats reared from six to 18 months of age on a high or medium plane of nutrition

The corresponding regression equations were;

57. $\text{Log}_{10} \text{ y (H)} = -3.92 + 3.13 \log_{10} x \text{ (H)}$ $R^2 = 62.9\%$

58. $\text{Log}_{10} \text{ y (M)} = -3.18 + 2.63 \log_{10} x \text{ (M)}$ $R^2 = 8.6\%$

59. $\text{Log}_{10} \text{ y (H+M)} = -3.65 + 2.95 \log_{10} x \text{ (H+M)}$ $R^2 = 39.3\%$

where y = cumulative fleece weight (kg), x = fibre diameter (μm).

Equations 57 and 58 were compared by analysis of covariance. The residual variances, gradients and intercepts of the two equations were not significantly different. There was therefore no significant effect of increasing the plane of nutrition from **M** to **H** on the relationship between fibre diameter and cumulative fleece weight in the present study.

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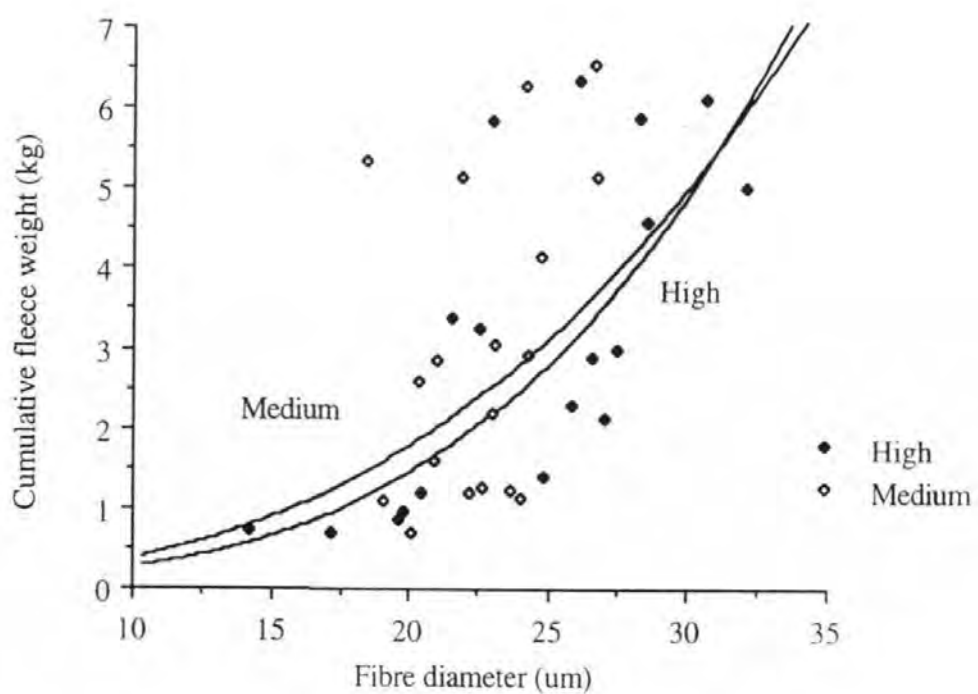
Figure 3.30

Logarithmic regression of cumulative fleece weight (kg) on fibre diameter (μm) of Angora
wether goats reared on a high or medium plane of nutrition from six to 18 months of age

(iii) The effect of a high or medium plane of nutrition on the relationships between body and fleece characteristics

Since fibre diameter appeared to be the main factor affecting the mass of fleece produced (section ii) the relationships between fibre diameter and EBW, and fibre diameter and body composition were examined.

Initially the consecutive changes in liveweight and fibre diameter with age were examined in treatment groups 24H, 24M and 24L (Figure 3.31). Since EBW and body composition data was only available for the slaughtered goats the subsequent correlations and regressions were performed using the data from treatment groups 6H/M, 12H, 18H, 12M and 18M.

Figure 3.31 shows the changes in mean liveweight and mean fibre diameter of treatment groups 24H and 24M with increasing age from six to 24 months (a and b respectively), the changes in mean liveweight and mean fibre diameter of the L plane slaughter groups with increasing age from six to 24 months and the effect of age on the mean fibre diameter of treatment group 24L from 12 to 24 months (Figure 3.31c). Liveweight data was not available for group 24L throughout the trial but it was assumed that the mean liveweight at each slaughter age was not significantly different from that of the slaughtered goats at the same age.

On the **H** plane of nutrition the increase in liveweight with age was accompanied by a simultaneous increase in fibre diameter up to 21 months of age (Figure 3.31a). The decline in feed intake to sub-maintenance quantities between 21 and 24 months (Figure 3.3) appeared to affect the relationship between liveweight and fibre diameter. A similar pattern of changes was evident in the **M** plane data but the data was more variable due to the more narrow range of values of liveweight and fibre diameter between six and 24 months of age (Figure 3.31b).

The data relating to goats aged 24 months on the **H** and **M** planes of nutrition was therefore excluded from the evaluation of the relationships between body weight and fibre diameter and body composition and fibre diameter since the decrease in feed intake at that age may have

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affected any existing relationships.

All data relating to the **L** plane of nutrition was similarly excluded due to the variation in the crude protein intake of those animals (Materials and methods) and to their failure to gain weight between 12 and 18 months of age which was accompanied by a decrease in fibre diameter (Figure 3.31c), both of which may have affected any relationship between body mass and fibre diameter.
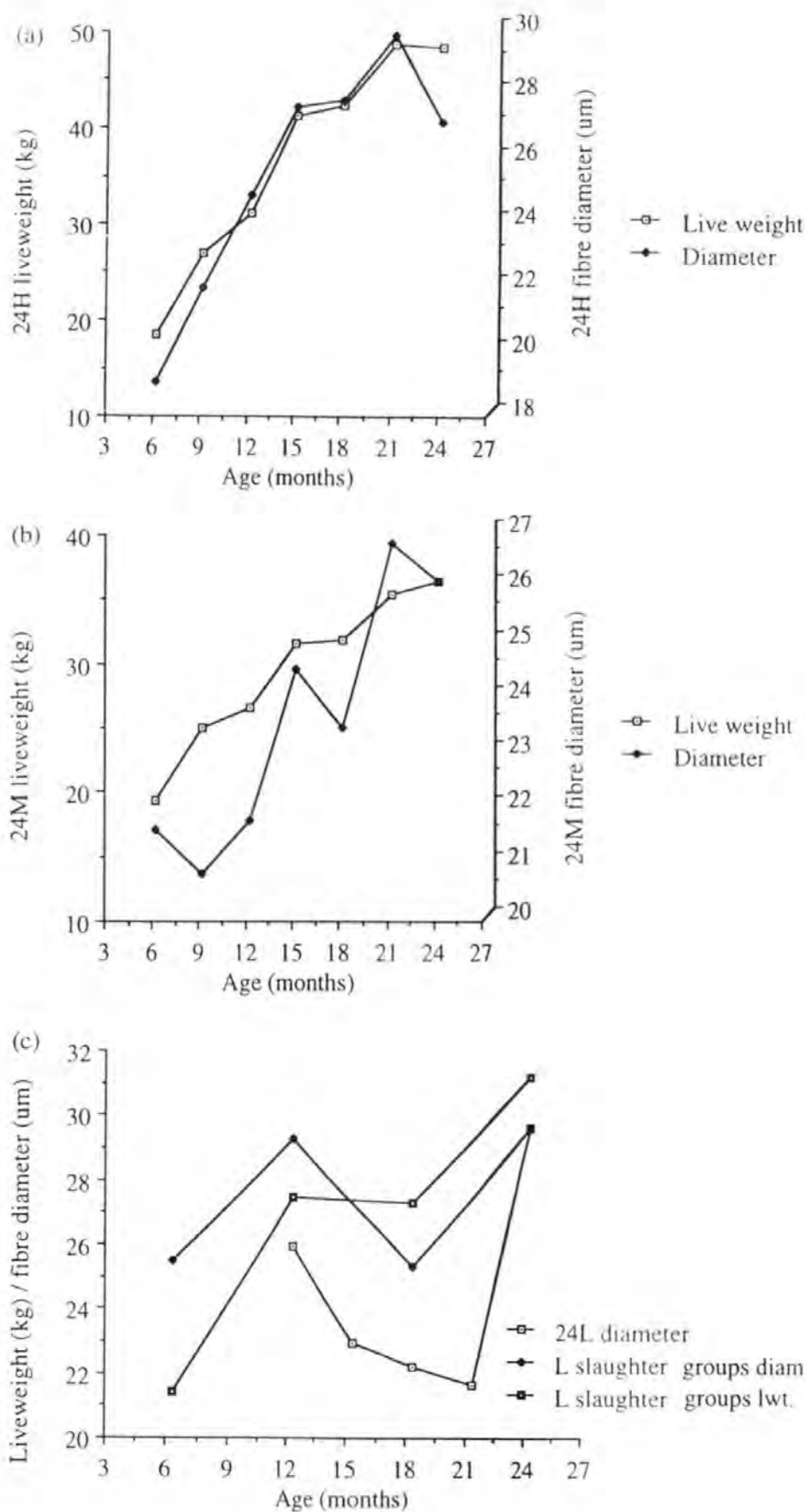
Figure 3.31

The effect of age on the mean liveweight and fibre diameter of Angora wether goats reared from six to 24 months of age on a high, medium or low plane of nutrition (treatment groups 24H, 24M and 24L respectively)

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On the **H** plane of nutrition there were high positive correlations between fibre diameter and all of the body and carcass components examined (Table 3.38). There were significant correlations between the same variables on the **M** plane of nutrition but the correlation coefficients were lower than on the **H** plane. This was again attributable to the more narrow range of values for fibre diameter and body components on the lower plane of nutrition. The combination of the data for both planes of nutrition produced significant correlations (P < 0.001) between fibre diameter and each body component examined.

	Plane of nutrition		
No.	High 18	Medium 18	Combined 30
Body component			
EBW (kg)	0.856***†	0.554*	0.822***
Fat free EBW (kg)	0.833***	0.489*	0.788***
Total body fat (kg)	0.858***	0.630**	0.826***
CCW (kg)	0.849***	0.584**	0.817***
Fat free CCW (kg)	0.817***	0.511*	0.772***
Total carcass fat (g)	0.867***	0.652**	0.843***

†Significance of correlation coefficient

Table 3.38

Correlation coefficients (r) between $\log_{10}$ fibre diameter (μm) and $\log_{10}$ body component of Angora wether goats reared from six to 18 months of age on a high or medium plane of nutrition

To determine whether there was a significant effect of plane of nutrition on the relationships between fibre diameter and body characteristics, regression equations were formulated to describe the relationships using the pooled data from the two treatments. Plane of nutrition was then added as an additional variable in the equations. An improvement in R^2 with a coefficient for plane of nutrition significantly different from zero indicated a significant effect of plane of nutrition on the relationship (Table 39).

There was a significant relationship between fibre diameter and EBW (Equation 60) which was not affected by plane of nutrition (Equation 61). Similarly when EBW was divided into

its fat and fat - free components there was a significant relationship between fibre diameter and fat-free EBW (Equation 62) and between fibre diameter and total body fat (TBF) (Equation 64), neither of which was affected by plane of nutrition. When both body components were combined in a multiple regression equation (Equation 66) the R^2 value of 65.0% was the same as that obtained when total EBW as a single predictor was used (Equation 60) and there was no effect of plane of nutrition on the relationship (Equation 67). Furthermore the contribution made by fat-free EBW to the multiple regression was negligible since its coefficient of 0.004 in Equation 66 was not significantly different from zero.

The relationship between fibre diameter and CCW was similarly examined (Equations 68 to 75). Again there were strong relationships between fibre diameter and CCW, fat-free CCW and total carcass fat which were not affected by plane of nutrition. The separation of total CCW into its fat and fat-free components increased R^2 from 64.4% (Equation 68) to 69.8% (Equation 74). The coefficient for fat-free CCW of 0.196 was not significantly different from zero, suggesting that the increased strength of the multiple regression was due to the greater influence of total carcass fat on the relationship.

Independent variates (x)	Regression equation	R^2 (%)
x_1 Log_{10} EBW (kg)	60. $y = 0.879 + 0.351\ x_1$	65.0
x_1 Log_{10} EBW (kg) x_2 Plane of nutrition	61. $y = 0.923 + 0.335\ x_1 - 0.0146\ x_2$	65.2
x_1 Log_{10} fat free EBW (kg)	62. $y = 0.803 + 0.439\ x_1$	60.1
x_1 Log_{10} fat free EBW (kg) x_2 Plane of nutrition	63. $y = 0.858 + 0.416\ x_1 - 0.0167\ x_2$	60.6
x_1 Log_{10} total body fat (kg)	64. $y = 1.23 + 0.190\ x_1$	66.1
x_1 Log_{10} total body fat (kg) x_2 Plane of nutrition	65. $y = 1.27 + 0.181\ x_1 - 0.0171\ x_2$	66.9
x_1 Log_{10} fat free EBW (kg) x_2 Log_{10} total body fat (kg)	66. $y = 1.24 - 0.004\ x_1 + 0.192\ x_2$	65.0
x_1 Log_{10} fat free EBW (kg) x_2 Log_{10} total body fat (kg) x_3 Plane of nutrition	67. $y = 1.30 - 0.033\ x_1 + 0.194\ x_2 - 0.0173\ x_3$	65.9
x_1 Log_{10} CCW (kg)	68. $y = 1.06 + 0.281\ x_1$	64.4
x_1 Log_{10} CCW (kg) x_2 Plane of nutrition	69. $y = 1.10 + 0.268\ x_1 - 0.0157\ x_2$	64.9
x_1 Log_{10} fat free CCW (kg)	70. $y = 1.07 + 0.318\ x_1$	57.8
x_1 Log_{10} fat free CCW (kg) x_2 Plane of nutrition	71. $y = 1.12 + 0.300\ x_1 - 0.0189\ x_2$	58.8
x_1 Log_{10} total carcass fat (kg)	72. $y = 1.24 + 0.214\ x_1$	68.9
x_1 Log_{10} total carcass fat (kg) x_2 Plane of nutrition	73. $y = 1.27 + 0.205\ x_1 - 0.0141\ x_2$	69.2
x_1 Log_{10} fat free CCW (kg) x_2 Log_{10} total carcass fat (kg)	74. $y = 1.36 - 0.196\ x_1 + 0.330\ x_2$	69.8
x_1 Log_{10} fat free CCW (kg) x_2 Log_{10} total carcass fat (kg) x_3 Plane of nutrition	75. $y = 1.38 - 0.191\ x_1 + 0.319\ x_2 - 0.0136\ x_3$	70.0

Table 3.39

Linear regression equations to describe the effect of a high or medium plane of nutrition on the relationships between log_{10} fibre diameter (y) and log_{10} various body characteristics (x)

4 Trial 2. Effect of level of realimentation on liveweight gain and carcass composition of the British Angora wether goat

4.1 Rationale and objectives

The commercially reared goats which comprised the L plane of nutrition in Trial 1 did not increase in empty body weight or warm carcass weight between 12 and 18 months of age. Their failure to increase in body mass at this age was accompanied by a non-significant decrease in the weight of dissectible fat in the half carcass and in the weights of their omental and KKCF deposits between six and 18 months of age, suggesting that the goats were kept on a sub-maintenance level of nutrition for much of this time (Table 3.5). The decrease in the mean fibre diameter of the same goats between 12 and 21 months of age also supported this suggestion (Table 3.35) and reflected the current priority of commercial Angora goat farmers which is to produce fine fibre for as long as possible at the expense of the growth of the carcass for meat production.

This system of production is likely to optimise returns from the sale of fibre but may have adverse effects on carcass yield, composition and meat quality. McMeekan (1940b) showed that pigs reared to a pre-determined liveweight on a low then high plane of nutrition made faster gains during the latter half of the experiment than pigs reared on a high plane of nutrition throughout. However, this "compensatory growth" consisted mainly of fat, since carcasses of the low-high pigs contained a greater proportion of fat and smaller proportions of lean and bone than carcasses of the high-high pigs. Pálsson and Vergés (1952) reported similar observations for the sheep.

McGregor (1984) demonstrated compensatory growth in the Angora goat, but the composition of the compensatory liveweight gain was unknown. In view of the unique fat distribution of the goat, it is possible that differences exist between the composition of compensatory growth of the goat and of other domestic species.

Therefore a second trial was designed to investigate the effects of realimentation of 18 month

old Texan x New Zealand Angora wether goats on their daily liveweight gain and carcass composition. The objectives of this experiment were to examine the effects of long term undernutrition on the subsequent growth rate of the British Angora wether goat between 25 and 30kg fleece-free liveweight, to compare the composition of the liveweight gain of the realimented goats with that of goats reared on an adequate (medium) plane of nutrition throughout, and to compare the effects of three levels of realimentation on the composition of liveweight gain of the British Angora wether goat.

4.2 Materials and methods

4.2.1 Experimental animals

The trial used 27 Texan x New Zealand Angora wether goats, approximately 18 months of age, with an initial mean fleece-free liveweight of 24.9 ± 2.3kg which were purchased from a single source.

Growth rate and body composition data relating to the goats reared on high, medium and low planes of nutrition from six to 24 months of age in Trial 1 were also used for purposes of comparison and to formulate prediction equations to estimate the body composition of goats reared on a medium plane of nutrition throughout.

4.2.2 Experimental design

The goats were randomly allocated to a control group, A, and three treatment groups B, C and D. The variable factor was the level of realimentation (high, medium or low) used to attain a total mean liveweight gain of 5kg per treatment group, with seven replicates per treatment group (Table 4.1). The initial mean fleece-free liveweights of the four groups were compared using a one way analysis of variance and found to be not significantly different (P > 0.05).

Treatment group	n	Level of realimentation	Expected DLWG (g)	Initial liveweight (kg)
A	6	Control	-	24.5
B	7	High	64.0	25.5
C	7	Medium	43.0	24.2
D	7	Low	29.0	25.5
s.e.				0.46
Significance				NS

Table 4.1

Summary of treatment groups in Trial 2 and their mean initial fleece-free liveweights

(i) Control group A

The control group A served two functions;

1. As the initial slaughter group it was used to estimate the initial body composition of the goats in Groups B, C and D from their initial liveweights. Group A was slaughtered immediately before the beginning of the trial and the left sides of the carcasses were jointed and dissected according to the procedures described for Trial 1. The body and carcass composition data of these six goats (Table 4.2) was used to derive relationships between liveweight and the weight of each body and carcass component (Table 4.3) from which the initial body composition of each of the goats allocated to treatment groups B, C and D was estimated.

2. The mean empty body weight and body composition data of Group A was compared with that of goats reared to the same age (18 months) on a high, medium or low plane of nutrition in Trial 1 (treatment groups 18H, 18M and 18L respectively) to determine the relative state of maturity of the Trial 2 goats at the beginning of the trial and to estimate their comparative growth rate up to 18 months of age (Table 4.2).

One way analysis of variance revealed that the mean empty body and cold carcass weights of Group A were significantly less than those of treatment groups 18H and 18M but not significantly different from those of treatment group 18L at 18 months of age (Table 4.2). Similarly the weights of the internal fat and carcass fat depots were significantly lower than those of treatment groups 18H and 18M but not significantly different from those of treatment group 18L. The weight of bone in the dissected half carcass did not differ significantly between treatment groups. The weight of lean in the dissected half carcass was significantly greater in group 18H than in the remaining treatment groups. There was a trend towards decreasing weight of lean with decreasing plane of nutrition but the weight of lean in treatment group 18L and Group A was similar.

Therefore the mean growth rate and body and carcass development of the Trial 2 goats up to

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Body component	Treatment group				s.e.	Significance
	18H	18M	18L	Group A		
EBW (kg)	43.9a	28.6b	23.2bc	21.4c	0.97	*
CCW (kg)	24.7a	14.8b	10.5c	10.2c	0.61	*
Omental fat (kg)	2.771a	1.212b	0.363c	0.429c	0.09	***
Mesenteric fat (kg)	1.150a	0.579b		0.357b	0.05	***
KKCF (kg)	2.204a	0.931b	0.229c	0.343c	0.05	***
Side bone (kg)	1.417	1.248	1.177	1.276	0.04	NS
Side lean (kg)	4.805a	3.003b	2.456b	2.516b	0.14	***
Side dissectible fat (kg)	3.861a	2.066b	1.078c	0.750c	0.15	***
Side IMF (kg)	1.389a	0.799b	0.473c	0.254c	0.05	***
Side SCF (kg)	2.472a	1.267b	0.605c	0.496c	0.10	***

Means in rows with different superscripts differ significantly

Table 4.2

Mean body composition of Angora wether goats reared to 18 months of age on a high, medium or low plane of nutrition (means of six goats)

$\log_{10}$ EBW (kg)	=	1.06 $\log_{10}$ liveweight (kg) - 0.14	$R^2 = 97.7\%$
$\log_{10}$ omental fat (g)	=	6.84 $\log_{10}$ liveweight (kg) - 6.96	$R^2 = 24.2\%$
$\log_{10}$ mesenteric fat (g)	=	7.85 $\log_{10}$ liveweight (kg) - 8.41	$R^2 = 59.6\%$
$\log_{10}$ KKCF fat (g)	=	8.45 $\log_{10}$ liveweight (kg) - 9.26	$R^2 = 79.0\%$
$\log_{10}$ CCW (kg)	=	2.03 $\log_{10}$ liveweight (kg) - 1.81	$R^2 = 77.5\%$
$\log_{10}$ bone (g)	=	1.18 $\log_{10}$ liveweight (kg) + 1.47	$R^2 = 32.3\%$
$\log_{10}$ lean (g)	=	1.48 $\log_{10}$ liveweight (kg) + 1.34	$R^2 = 49.9\%$
$\log_{10}$ IMF (g)	=	8.40 $\log_{10}$ liveweight (kg) - 9.34	$R^2 = 47.9\%$
$\log_{10}$ SCF (g)	=	7.90 $\log_{10}$ liveweight (kg) - 8.35	$R^2 = 41.1\%$
$\log_{10}$ total fat (g)	=	8.06 $\log_{10}$ liveweight (kg) - 8.40	$R^2 = 43.6\%$

Table 4.3

Prediction equations relating $\log_{10}$ body component (y) to $\log_{10}$ liveweight (x) of Group A goats and used to predict the initial body composition of goats in Groups B, C and D

18 months of age was not significantly different from that of the L plane goats in Trial 1 up to the same age (Figure 4.1).

(ii) Treatment groups B, C and D

The goats assigned to treatment groups B, C and D were indoor housed in three pens approximately 5m x 5m. The treatment groups were mixed and randomly allocated to the three pens, seven goats per pen. The goats were bedded on straw with free access to water and salt licks. They were individually fed, twice per day, in custom built stalls and weighed every week before the first feed in the morning to minimise variation in gut fill.

The daily liveweight gain of the goats was controlled by varying their individual ration of a diet identical to that used in Trial 1. The ration consisted of an estimated maintenance component calculated to provide 0.42 MJ ME/kg$^{0.75}$, which was adjusted weekly, plus a fixed amount to allow the predetermined daily liveweight gain for each goat (Table 4.1). The feed requirement for growth was calculated from the dry matter intakes and the growth rates achieved by the M plane goats in Trial 1 over the same weight range of 25 to 30kg fleece-free liveweight. Group B was fed to achieve the same daily liveweight gain as the Trial 1 M plane goats. Group C was fed to achieve a daily liveweight gain of approximately 66% that of Group B. Group D was fed to achieve a daily liveweight gain of approximately 66% that of Group C (Figure 4.2).

The goats were shorn and slaughtered when the average treatment group liveweight reached 5kg more than its mean starting liveweight, with an allowance for fleece cover which was estimated from the results of Trial 1. The slaughter and dissection procedures were as described for Trial 1.
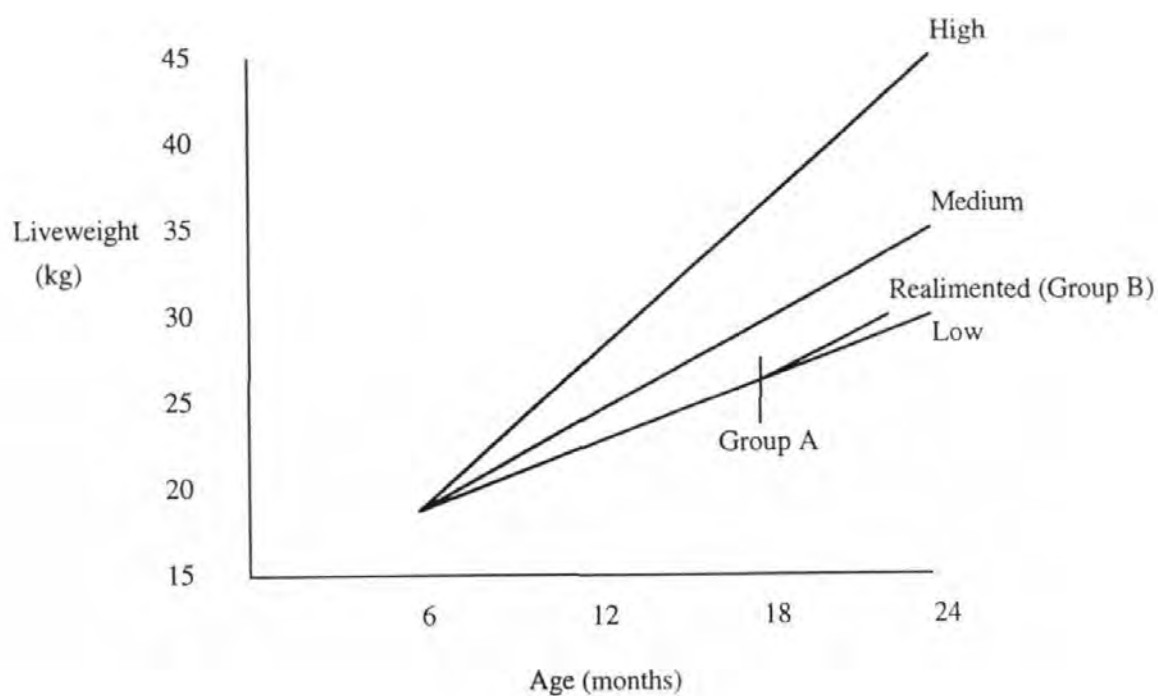
Figure 4.1

Schematic representation of the growth of realimented goats in Trial 2 compared with the growth of goats reared on a high, medium or low plane of nutrition in Trial 1
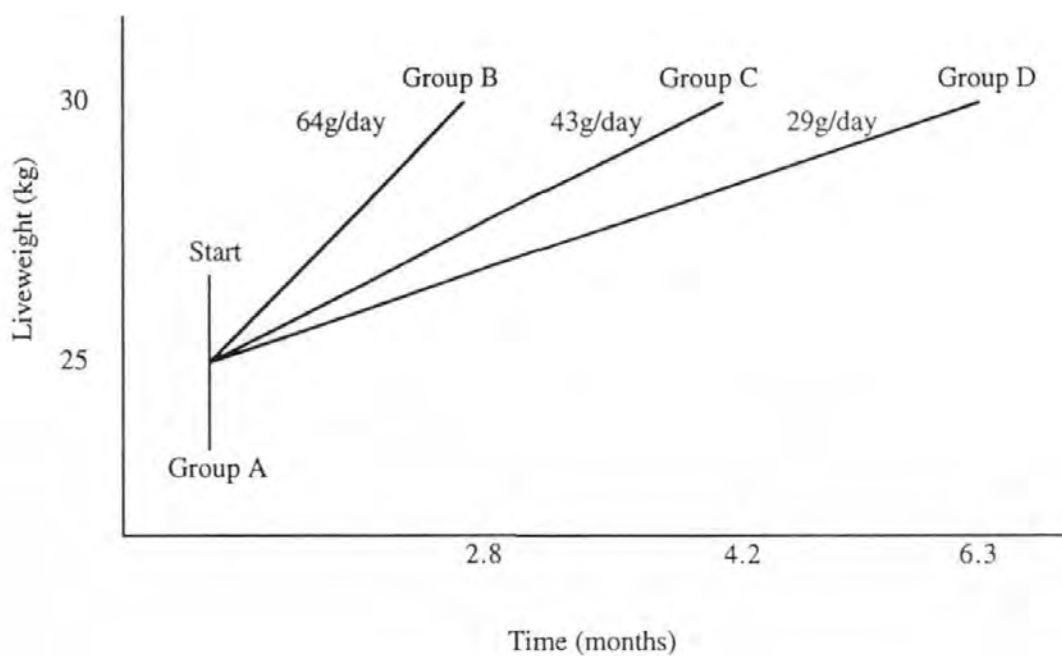
Figure 4.2

Schematic representation of the growth of goats reared on three levels of
realimentation in Trial 2

4.3 Results and discussion

4.3.1 The effect of long term undernutrition on the subsequent growth rate of the British Angora wether goat between 25 and 30kg fleece-free liveweight.

(i) Feed intake

It was necessary to shear group B three days before they were slaughtered. This period coincided with a particularly cold spell of weather. Contrary to the results in section 3.3.2 the shorn goats in this experiment suffered a *loss* of appetite immediately after shearing which was not evident in the unshorn goats. Forbes (1986) reported that in hens, pigs, cattle and dairy cows a reduction in the effective temperature to -20°C resulted in significant increases in feed intake and that the feed intake of sheep generally increases within a week of shearing. It is possible that the poor subcutaneous fat cover of the goats in Trial 2, which was estimated to be approximately equal to that of treatment group 18L in Trial 1 (Appendix IV), combined with Winter shearing, resulted in an extreme form of cold stress which is unlikely to be experienced by other domestic livestock in normal commercial situations. As a result of their depressed feed intake these goats lost between 0.75 and 1.85kg liveweight per goat between shearing and slaughter. The majority of this weight loss was probably due to a reduction of gut fill rather than to mobilisation of reserves but the decline in liveweight resulted in a mean liveweight gain of group B which was significantly less than that of group C (Table 4.5). Groups C and D were shorn and slaughtered on the same day so that the problem did not recur. Therefore the mean daily feed intakes and daily live weight gains were calculated using the last fleece-corrected liveweights prior to shearing† rather than the slaughter weights, for accurate comparison of the growth performance of the three treatment groups.

Dry matter, crude protein and energy intakes per kg liveweight$^{0.75}$ were significantly different between treatment groups (Table 4.4). As expected, the efficiency of conversion of feed to liveweight gain decreased with decreasing plane of nutrition but the differences were

not statistically significant.

	Treatment group			s.e.	Significance
	B	C	D		
DM (g/kg liveweight$^{0.75}$)	73.8[a]	65.5[b]	59.2[c]	0.57	***
CP (g/kg liveweight$^{0.75}$)	8.4[a]	7.5[b]	6.8[c]	0.06	***
Energy (MJ ME/kg liveweight$^{0.75}$)	0.66[a]	0.59[b]	0.53[c]	0.01	***
kg DM/kg LWG	15.8	18.7	21.3	1.31	NS

Means in rows with different superscripts differ significantly

Table 4.4

Mean daily nutrient intakes of Angora wether goats realimented on three planes of nutrition from 25 to 30kg liveweight (means of 7 goats)

(ii) Growth performance

The mean daily liveweight gain was highest for group B (58.5g/day) and lowest for group D (36.1g/day). The actual mean rate of gain was lower than predicted for group B but greater than predicted for groups C and D which made the differences between the treatment groups smaller than were planned. Consequently the mean daily liveweight gain of group B was significantly greater than that of group D but there were no significant differences between consecutive feed levels (Table 4.4).

The actual mean growth rate of Group B of 58.5g/day was not greater than its expected growth rate of 64g/day which was achieved by goats reared on a continuous medium plane of nutrition in Trial 1 (Figure 4.1). Therefore there was no evidence of compensatory liveweight gain in the realimented goats.

| | Treatment group | | | | |
	B	C	D	s.e.	Significance
Fleece-free liveweights (kg)					
at entry	25.5	24.2	25.5	0.56	N.S.
at slaughter	28.5	29.6	29.8	0.56	N.S.
at finish†	29.6	29.1	29.8	0.52	N.S.
Total LWG (kg)					
entry to slaughter	3.0a	5.4b	4.3ab	0.34	*
entry to finish	4.1	4.8	4.2	0.32	N.S
Days from entry to finish	70	105	119		
DLWG (g) entry to finish	58.5a	46.5ab	36.1b	3.23	*
Expected DLWG (g)	64.0	43.0	29.0		

Means in rows with different superscripts differ significantly;
†Last fleece-corrected liveweight prior to shearing

Table 4.5

Effect of level of realimentation from 25 to 30kg liveweight on the mean growth performance of 18 month old Angora wether goats (means of 7 goats)

4.3.2 Comparison of the composition of the liveweight gain of 18 month old British Angora wether goats realimented on a medium plane of nutrition with that of goats reared on a medium plane of nutrition throughout

The equations derived from the body composition data of Group A (Table 4.3) were used to estimate the initial body composition of each of the goats in Group B from its initial liveweight (Table 4.7). Due to unforeseen circumstances the mean liveweight gain of Group B following realimentation on the **M** plane of nutrition was only 3.01kg (Table 4.5) which equated to a mean EBW gain of 3.33kg. The composition of the total EBW gain was calculated for each goat as the difference between the measured composition at slaughter and the estimated composition at the start of the trial (Table 4.7).

Using data derived from Trial 1 from the goats reared on the **M** plane of nutrition throughout, equations were formulated for the prediction of body composition from fat-free EBW (Table 4.6). The body composition of six hypothetical goats reared to equal initial fat-free EBW's as the Group B goats (mean initial fat-free EBW = 18.66kg) on the **M** plane of nutrition was estimated from the equations (Table 4.7). These goats shall henceforth be referred to as the **M** plane goats. Allowing a total EBW gain of 3.33kg per goat the final body composition of the **M** plane goats was also estimated using the prediction equations and the composition of EBW gain was calculated as for the Group B goats (Table 4.7).

In this way the composition of the realimented EBW gain of the Group B goats could be compared with that of goats reared on a constant **M** plane of nutrition from the same initial fat-free EBW. The mean composition of 3.33kg EBW gain of the two treatment groups, Group B and **M** plane, was compared by one way analysis of variance (Table 4.7).

With the exception of fat-free CCW and half carcass bone there was no significant difference in the weight gained by any other body component between the two groups of goats. The **M** plane goats appeared to partition significantly more of their total weight gain into fat-free CCW than the Group B goats (1.297 v 0.660kg respectively, P < 0.01). This was due to the growth of significantly more half carcass bone in the **M** plane goats (0.165kg) than in Group

B (-0.063kg, P < 0.001) while the growth of half carcass lean was not significantly affected by the treatments. The initial weight of half carcass bone in Group B was high compared with that of the M plane goats (1.319 v 1.063kg respectively) while the final weight of bone in the two groups was similar (1.256 v 1.227kg respectively) resulting in an apparent weight loss of bone in Group B and a gain in the M plane goats. Since the equation used to predict initial half carcass bone in Group B had an R^2 value of only 32.3% (Table 4.3) it seemed likely that the significant difference between the two treatments in the mass of bone growth was due to error in the prediction of the initial weight of bone of Group B rather than to a real treatment effect.

There was therefore no significant effect of long-term undernutrition on the composition of subsequent empty body weight gain.

Prediction equation			R^2 (%)
Log_{10} EBW	=	-0.262 + 1.29 log_{10} fat-free EBW	98.0
Log_{10} omental fat	=	-3.21 + 2.45 log_{10} fat-free EBW	80.4
Log_{10} KKCF	=	-3.34 + 2.46 log_{10} fat-free EBW	87.4
Log_{10} mesenteric fat	=	-1.62 + 1.04 log_{10} fat-free EBW	35.2
Log_{10} fat-free CCW	=	-0.944 + 1.46 log_{10} fat-free EBW	95.6
Log_{10} side lean	=	-1.43 + 1.45 log_{10} fat-free EBW	90.3
Log_{10} side bone	=	-1.75 + 1.40 log_{10} fat-free EBW	81.0
Log_{10} side dissectible fat	=	-2.54 + 2.12 log_{10} fat-free EBW	90.3
Log_{10} side IMF	=	-2.80 + 2.01 log_{10} fat-free EBW	88.4
Log_{10} side SCF	=	-2.89 + 2.22 log_{10} fat-free EBW	84.6

Table 4.6

Linearised allometric equations used to predict the empty body composition (kg) from fat-free EBW (kg) of goats reared on the medium plane of nutrition from six to 24 months of age in Trial 1

Body component	Initial weight (kg)		Final weight (kg)		Weight gain (kg)			
	Group B	Medium plane	Group B	Medium plane	Group B	Medium plane	s.e.	Sig.
EBW	21.83 (2.14)	23.50 (0.73)	25.16 (1.38)	26.83 (0.73)	3.33 (1.29)	3.33 (0.00)	0.26	NS
Fat-free EBW	18.66 (0.45)	18.66 (0.45)	20.87 (1.19)	20.69 (0.44)	2.21 (1.32)	2.03 (0.01)	0.27	NS
Omental fat	0.463 (0.31)	0.777 (0.04)	0.908 (0.23)	1.013 (0.05)	0.445 (0.37)	0.237 (0.01)	0.08	NS
Mesenteric fat	0.446 (0.34)	0.503 (0.01)	0.519 (0.08)	0.564 (0.01)	0.073 (0.35)	0.061 (0.00)	0.07	NS
KKCF	0.450 (0.37)	0.619 (0.04)	0.636 (0.19)	0.801 (0.04)	0.186 (0.33)	0.182 (0.00)	0.07	NS
Fat-free CCW	8.49 (0.37)	8.16 (0.29)	9.15 (0.71)	9.46 (0.29)	0.660 (0.48)	1.297 (0.01)	0.10	**
Side lean	2.572 (0.35)	2.564 (0.09)	2.889 (0.26)	2.977 (0.09)	0.317 (0.17)	0.414 (0.00)	0.04	NS
Side bone	1.319 (0.14)	1.063 (0.04)	1.256 (0.09)	1.227 (0.04)	-0.063 (0.11)	0.165 (0.00)	0.02	***
Side dissectible fat	0.908 (0.71)	1.441 (0.07)	1.105 (0.10)	1.800 (0.08)	0.197 (0.69)	0.359 (0.01)	0.14	NS
IMF	0.317 (0.26)	0.581 (0.03)	0.367 (0.04)	0.715 (0.03)	0.050 (0.26)	0.134 (0.00)	0.05	NS
SCF	0.604 (0.46)	0.862 (0.05)	0.738 (0.09)	1.084 (0.05)	0.135 (0.44)	0.222 (0.00)	0.09	NS

Table 4.7

Mean empty body composition of Angora wether goats reared on a low plane of nutrition to 21.83kg EBW and then on a medium plane of nutrition to 25.16kg EBW (Group B), estimated empty body composition of goats reared on a medium plane of nutrition to a comparable fat-free EBW and then to a comparable total EBW gain of 3.33kg on a medium plane of nutrition (Medium plane) and comparison of the composition of EBW gain of the two groups of goats (means of six goats)

4.3.3 The effect of level of realimentation of 18 month old British Angora wether goats on the composition of their subsequent liveweight gain

The mean composition of the realimented empty body weight gain of treatment groups B, C and D was compared. The initial body composition of the goats allocated to each treatment group was estimated from their liveweight at entry and the relationships between liveweight and body composition derived from group A (Table 4.8). Changes in body composition from the start of the trial to slaughter were calculated for individual animals as the difference between the measured composition at slaughter and the estimated initial composition (Table 4.9). Since the mean total EBW gains of the three treatment groups were not equal the daily rate of gain of each body component was compared using a one way analysis of variance.

There was an increase in the weight of most body components in all three treatment groups following realimentation (Table 4.9). Half carcass bone did not increase under any level of realimentation. This was expected in view of the early maturing nature of bone tissue. The apparent loss of weight of bone in groups B and D was attributable to the tendency of the prediction equation for bone to over estimate the initial weight of bone in the half carcass.

The loss of the dissection data for the heaviest goat in Group B and the three lightest goats in Group C led to slightly misleading mean values for half carcass composition. In view of the small number of goats in each treatment group and the high variation in the data this was unlikely to have affected the significance of the results.

There was no significant effect of level of realimentation on the daily weight gain of any of the body components examined (Table 4.9).

Upon completion of this second experiment it became apparent that possibly more illuminating results might have been achieved with several modifications to the trial design. The allocation of a total of nine goats to the control group, A, would have produced more accurate equations for the prediction of the initial empty body composition of the goats than was achieved by including only six goats, as described in Section 4.2.2., while still allowing six replicates per treatment in groups B, C and D. It was also found that following the random allocation of the goats to the four treatment groups, A, B, C and D, the heaviest animals were not included in group A. Consequently the initial body composition of these heavier animals had to be predicted from equations which did not in fact extend to such high values. Including the lightest and heaviest animals in group A would have improved the accuracy of the predictions of initial body composition and this may have affected the final outcome of the results.

It would also have been useful to have included a group either fed *ad lib.*, with 24 hour access to the feed, or at least permitted to feed 'to appetite' at each feeding, since it has been suggested that compensatory liveweight gain is simply a result of increased feed intake promoting normal rates of gain (Winter, 1971; Stamataris *et al.*, 1991) or, in cases where liveweight rather than empty body weight have been recorded, due to increased gut fill (McMeekan, 1940c; Thornton *et al.*, 1979). The realimented goats in the present study were, in effect, still restricted and in retrospect treatment D should have been replaced by unrestricted feeding. Furthermore the diet fed in the present study was of low nutrient density since, for reasons of economics and due to restricted storage space, it was the same as that fed to the goats in Trial 1 (Appendix 1). Consequently the rates of gain achieved by the three treatment groups were probably too low and too similar to demonstrate either the existence or otherwise of compensatory growth in the Angora wether goat or an effect of rate of realimentation on the composition of compensatory liveweight gain. Feeding a better quality diet might have yielded more useful results.

	Initial weight (kg)						Final weight (kg)					
	Group B		Group C		Group D		Group B		Group C		Group D	
n	7		7		7		7		7		7	
Liveweight	25.48	(2.45)	24.22	(2.23)	25.52	(2.92)	28.49	(2.01)	29.60	(2.06)	29.83	(3.35)
EBW	22.27	(2.27)	21.10	(2.05)	22.31	(2.70)	25.70	(1.91)	27.04	(2.07)	26.80	(2.86)
Omental fat	0.531	(0.33)	0.371	(0.23)	0.572	(0.45)	0.967	(0.26)	1.076	(0.21)	0.975	(0.24)
Mesenteric fat	0.521	(0.37)	0.345	(0.25)	0.575	(0.52)	0.531	(0.07)	0.629	(0.07)	0.574	(0.10)
KKCF	0.531	(0.40)	0.340	(0.26)	0.594	(0.58)	0.664	(0.19)	0.750	(0.23)	0.700	(0.13)
CCW	11.17	(2.18)	10.08	(1.87)	11.25	(2.61)	12.32	(1.18)	13.64	(1.67)	13.29	(2.19)
n	6		4		7		6		4		7	
Fat-free EBW	18.66	(0.45)	17.70	(2.18)	18.21	(1.57)	20.87	(1.18)	22.35	(1.11)	21.94	(1.80)
Side lean	2.572	(0.35)	2.486	(0.46)	2.655	(0.45)	2.888	(0.26)	3.326	(0.34)	3.255	(0.55)
Side bone	1.319	(0.14)	1.282	(0.19)	1.351	(0.18)	1.256	(0.09)	1.320	(0.02)	1.321	(0.09)
Side dissectible fat	0.908	(0.71)	0.816	(0.68)	1.180	(1.10)	1.105	(0.10)	1.668	(0.47)	1.294	(0.35)
IMF	0.317	(0.26)	0.284	(0.25)	0.419	(0.41)	0.367	(0.04)	0.587	(0.18)	0.491	(0.17)
SCF	0.603	(0.46)	0.549	(0.46)	0.779	(0.71)	0.738	(0.09)	1.080	(0.31)	0.803	(0.19)

Table 4.8

Mean initial and final weights of body components of Angora wether goats reared on a low plane of nutrition to 18 months of age (initial weight) and then realimented on a low, medium or high plane of nutrition to a mean liveweight gain of approximately 5kg per treatment group

	Total weight gain (kg)			Daily weight gain (g)				
	Group B	Group C	Group D	Group B	Group C	Group D	s.e.	Sig.
n	7	7	7	7	7	7		
Liveweight	3.01 (1.12)	5.38 (2.11)	4.31 (1.20)	40.15	48.87	34.71	3.28	NS
EBW	3.43 (1.21)	5.94 (1.78)	4.49 (1.14)	45.73	53.99	36.20	3.11	NS
Omental fat	0.436 (0.34)	0.705 (0.20)	0.404 (0.35)	15.82	6.41	3.26	0.71	NS
Mesenteric fat	0.009 (0.36)	0.284 (0.23)	0.000 (0.46)	0.12	2.59	0.00	0.81	NS
KKCF	0.133 (0.34)	0.410 (0.14)	0.106 (0.51)	1.77	3.73	0.86	0.78	NS
CCW	1.15 (1.27)	3.57 (1.54)	2.04 (1.13)	15.30	32.41	16.42	3.00	NS
n	6	4	7	6	4	7		
Fat-free EBW	2.21 (1.31)	4.65 (1.10)	3.73 (3.02)	29.42	42.22	30.05	4.76	NS
Side lean	0.316 (0.17)	0.841 (0.27)	0.601 (0.30)	4.22	7.64	4.85	0.58	NS
Side bone	-0.063 (0.11)	0.038 (0.19)	-0.030 (0.19)					
Side dissectible fat	0.197 (0.69)	0.852 (0.56)	0.114 (0.76)	2.63	7.75	0.92	1.74	NS
IMF	0.049 (0.26)	0.303 (0.23)	0.072 (0.24)	0.66	2.76	0.58	0.64	NS
SCF	0.135 (0.44)	0.538 (0.34)	0.025 (0.54)	1.80	4.89	0.20	1.15	NS

Table 4.9

Mean total weight gain of body components during realimentation period and comparison of daily weight gain of each body component of Angora wether goats reared on a low plane of nutrition to 18 months of age (initial weight) and then realimented on a low, medium or high plane of nutrition to a mean liveweight gain of approximately 5kg per treatment group

5 Conclusions

The fundamental laws of allometry, heterogenic growth, centripetal development and the order of developmental priority of different parts, organs and tissues which have been established for other species of domestic livestock and breeds of goat also apply to the British Angora goat. Thus between six months of age and maturity there is a definite order of development of the main body parts which is, in order of maturity, vital organs, external offal, carcass and body fat, the order of developmental priority being related to the physiological function of the part. The organs vital to the survival of the animal are therefore the earliest maturing and most rapidly developing parts in the young goat, followed closely by the head which is of primary importance as a protective container for the brain and sensory organs. Body fat is the latest developing part, being primarily a storage tissue for nutrients excess to the immediate requirements of the animal and is therefore most rapidly developing in the older goat when all other parts and tissues have achieved their maximum relative growth rate.

The centripetal pattern of development is reflected in the relative order of development of the external offal, the head and feet being earlier maturing than the pelt, and in the linear development of the carcass which grows initially by increased leg length, first lower then upper leg, and by increased carcass length and then depth, all of which underline the early development of the skeleton. The later increases in carcass width and circumference of the buttocks are a reflection of the later maturity of carcass muscle and fat tissues. The centripetal growth pattern is also reflected in the relative growth rates and order of development of the commercial carcass joints which mature in the following order; shoulder, leg, chump, loin, breast, best end. Thus in the young goat the most rapid growth is in the limb joints, a wave of increasing relative growth intensity converging on the more centrally positioned joints as the animal matures.

There is a clear order of development of the body fat depots, similar to that reported for other domestic species. In order of decreasing maturity this is; visceral, mesenteric, intermuscular, subcutaneous, omental and KKCF. Under conditions of sub-maintenance nutrient intake

these fat depots are mobilised in reverse order of their maturity, KKCF being most rapidly mobilised followed closely by omental fat while the carcass dissectible fat depots remain largely unaffected. Thus it appears that in the goat fat mobilisation is not the exact reverse process of fat accretion which would have resulted in a proportional decrease in all body fat depots. For this reason the internal fat depots are unsuitable predictors of carcass dissectible fat where there is a possibility that fat mobilisation may have occurred.

There is no effect of variation in the plane of nutrition on the differential growth patterns of the fat-free empty body or carcass of the goat. Decreasing the plane of nutrition from high to low results in a uniform retardation of the whole body, the parts, organs and tissues of which remain in proportion relative to its fat-free weight. The growth of fat relative to that of the fat-free empty body or carcass is, however, dependent on the plane of nutrition, an increase of which results in more rapid fat deposition in all fat depots and a greater proportion of fat at equal total empty body or carcass weights. There is no effect of rate of fat deposition on the partitioning of total fat into the various depots except when fat mobilisation has occurred, this resulting in a greater proportion of the earlier maturing carcass dissectible fat depots and a lower proportion of internal fat depots.

The differential development of the carcass tissues within the half carcass remain unaffected by variation in the plane of nutrition. Consequently sample joint composition accurately reflected the composition of the half carcass when the data from all three planes of nutrition were combined in the present study. The leg and the best end are the most accurate predictors of whole carcass composition when combined in multiple regression equations and it is hoped that the proposed prediction equations will be of use in future studies of Angora goat growth and nutrition to avoid the arduous and costly task of half carcass dissection. However it must be emphasised that the equations are only appropriate for the prediction of the body composition of Angora wether goats having an empty body weight of between 16 and 60kg which is the range of empty body weights used in the formulation of the equations.

The observed effects of plane of nutrition on the absolute growth rates of the fat-free empty body and carcass and on the relative growth rates of total body and carcass fat explain the

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differences found in body and carcass composition and conformation of the goats slaughtered at six-monthly intervals on the three planes of nutrition. The low-plane series of commercially reared goats clearly demonstrates the current policy of Angora goat producers of maintaining their goats on as low a nutrient intake as possible, even to the point of weight loss, in order to maintain fibre fineness for up to two years. Their methods are justified in the clear increase in fibre diameter with increasing plane of nutrition observed in the present study, which would incur price penalties in the commercial mohair market.

The higher planes of nutrition confirm that the Angora wether goat has the potential to produce a meat carcass with reasonable conformation in terms of joint proportions, with lean:bone ratios which can be comparable with lamb carcasses of equal maturity and a more favourable fat content and partitioning than has been reported for other breeds of goat. It still remains that the Angora goat is slower growing and thus later maturing than most breeds of sheep which may have consequences on meat quality. This requires further investigation. Furthermore, despite having a greater proportion of subcutaneous fat than most other breeds of goat, the distribution of this fat is not entirely favourable, back fat thickness being characteristically low in all but the most obese animals. This not only has deleterious effects on carcass conformation but may also have consequences on meat quality which may have to be dealt with in terms of the post-slaughter treatment of the carcass.

In addition to the undeniable benefits regarding carcass yield, quality and conformation, increasing the plane of nutrition also improved cumulative fleece yield, but this was achieved solely by means of greater fibre diameter with no concomitant increase in staple length. Thus there is no potential for more frequent shearing of goats reared on a higher plane of nutrition due to the requirement of mohair processors for a minimum staple length of 7.5cm, price penalties being incurred for shorter fleeces. Fibre diameter appears to be directly related to cumulative feed intake since there was a strong positive relationship between diameter and the weights of all body and carcass components, the relationship with body fat being particularly strong and unaffected by plane of nutrition. Consequently the use of higher planes of nutrition to increase growth rates and advance carcass maturity to produce a saleable carcass within 18 months will unavoidably result to some extent in an increase in fibre diameter.

However, large increases in fibre diameter may be averted by the avoidance of unnecessarily high levels of total fat deposition. The information provided in this study regarding the order of development of the various fat depots and the relationships between the depots and total weight of fat should go some way towards enabling producers to determine when optimum carcass fatness has been achieved and avoid the further wasteful deposition of omental and KKCF, thus avoiding unnecessary increases in fibre diameter.

It is possible that improvements in growth rate and carcass composition without adverse effects on fibre quality may be achieved via the manipulation of diet quality, for example by varying the ratios of energy to protein or of rumen degradable protein to undegradable protein. These matters require further investigation.

In the meantime it seems likely that when the price for fine mohair is at a premium producers will continue to grow the finest possible fibre at the expense of the growth of the goat and then attempt to feed up the 18-month-old animal to produce a saleable carcass. This being the case the results of experiment two are encouraging in that, while there is no evidence of compensatory liveweight gain in Angora goats of this age there are also no permanent adverse effects of long-term under nutrition on the subsequent growth rate and composition of empty body weight gain of the goats. Thus it should be feasible to increase the carcass weight at 18 months of age by means of increased lean and carcass fat deposition and not merely by increased internal fat deposition, which had been the point of concern. However, the increased age at maturity of such animals may have consequences on meat quality, and this also needs further investigation.

It is hoped that the results of this study will assist and encourage Angora goat producers to develop a meat industry capable of affording some stability to the volatile mohair industry. Successful marketing will be required to promote the home consumption of UK produced goat meat and to encourage demand from foreign markets. Given a stable source of income mohair producers should be better able to expand their numbers to allow large-scale production of quality fibre which can compete economically with imported fibre from South Africa, Australasia and the USA in the UK processing market.

Appendix I

Composition of experimental ration

	%
Wheat	5.00
Wheatfeed	24.40
Untreated straw	35.00
Oatmeal by-product	10.00
Ext. sunflower	6.57
Fat	2.08
Molaferm	12.37
Limestone	1.53
Dicalcium phosphate	0.99
Rock salt	1.26
Ammonium sulphate	0.40
Mins/vits	0.40

Analysis as fed

Crude protein	%	10.00
ME	MJ/kg	7.85
Calcium	%	1.20
Phosphorus	%	0.50
Sodium	%	0.60
Magnesium	%	0.26
Dry matter	%	88.0
Crude protein	g/kg DM	113.64
ME	MJ/kg DM	8.92
g CP/MJ ME		12.74

Dependent variable (y)	Treatment	n	$\log_{10} a$	Allometric coefficient (b)	R^2 (%)	Significance a	b	R^2
WCW (kg)	H	24	-0.589	1.217	99.2	***	***	***
	M	24	-0.675	1.281	98.8	***	***	***
	L	24	-0.361	1.041	89.6	**	***	***
Total body fat (kg)[†]	H	18	-1.431	1.581	92.7	***	***	***
	M	18	-1.556	1.642	95. 6	***	***	***
	L	12	0.359	0.132	0.0	***	NS	NS
Pelt (kg)[‡]	H	18	-0.588	0.764	87.9	***	***	***
	M	18	-0.527	0.724	78.7	**	***	***
	L	24	-0.646	0.797	24.9	NS	**	**
Feet (kg)	H	24	-1.154	0.684	94.0	***	***	***
	M	24	-1.248	0.759	90.2	***	***	***
	L	24	-1.402	0.916	75.4	***	***	***

Table 1.1

Linearised allometric equations for the growth of body components and organs (y) relative to the growth of the empty body (x). Equation of the form $\log_{10} y = \log_{10} a + b \log_{10} x$. Significance levels indicate the significance of the intercept and the gradient (allometric coefficient) from zero and the significance of the fit of the equation to the data (R^2).

Dependent variable (y)	Treatment	n	$\log_{10} a$	Allometric coefficient (b)	R^2 (%)	Significance		
						a	b	R^2
Head (kg)#	H	24	-0.899	0.710	84.4	***	***	***
	M	24	-1.302	1.039	74.6	***	***	***
	L	24	-0.898	0.849	48.9	**	***	***
Heart (kg)	H	24	-2.061	0.755	90.7	***	***	***
	M	24	-2.251	0.900	73.1	***	***	***
	L	24	-2.623	1.241	57.7	NS	***	***
Lungs (kg)	H	24	-0.914	0.173	5.8	***	NS	NS
	M	24	-0.654	-0.039	0.0	***	NS	NS
	L	24	-2.813	1.538	68.5	NS	***	***
Liver & spleen (kg)	H	24	-1.080	0.588	74.3	***	***	***
	M	24	-0.916	0.442	43.9	***	***	***
	L	24	-2.237	1.411	80. 7	**	***	***
Kidneys (kg)	H	24	-1.927	0.614	78. 9	***	***	***
	M	23	-1.815	0.530	71. 8	***	***	***
	L	24	-2.506	1.017	76. 3	**	***	***

†Excludes treatment groups 6H/M, 12L and 18L;

‡ Excludes treatment groups 24H and 24M;

includes oesophagus and trachea.

Table 1.1 (continued)

Dependent variable (y)	Treatment	n	$\log_{10} a$	Allometric coefficient (b)	R^2 (%)	Significance a	b	R^2
Bone (kg)	H	24	-0.616	0.586	74.7	***	***	***
	M	24	-0.827	0.800	78.6	***	***	***
	L	24	-0.733	0.784	53.1	***	***	***
Lean (kg)	H	24	-0.433	0.786	93.0	***	***	***
	M	24	-0.509	0.859	93.9	***	***	***
	L	24	-0.979	1.337	87.9	***	***	***
Carcass dissectible	H	24	-1.250	1.320	95.9	***	***	***
fat (kg)	M	24	-1.193	1.267	95.5	***	***	***
	L	24	-0.721	0.719	35.6	***	**	**
IMF (kg)	H	24	-1.532	1.214	94.0	***	***	***
	M	24	-1.508	1.193	91.6	***	***	***
	L	24	-1.220	0.816	25.8	***	**	**

Table 1.2

Linearised allometric equations for the growth of half carcass tissues and commercial joints (y) relative to the growth of the cold carcass (x). Equation of the form $\log_{10} y = \log_{10} a + b \log_{10} x$. Significance levels indicate the significance of the intercept and the gradient (allometric coefficient) from zero and the significance of the fit of the equation to the data (R^2).

Dependent variable (y)	Treatment	n	$\log_{10} a$	Allometric coefficient (b)	R^2 (%)	Significance a	b	R^2
SCF (kg)	H	24	-1.569	1.403	93.9	***	***	***
	M	24	-1.487	1.327	89.3	***	***	***
	L	24	-0.900	0.671	23.1	***	*	*
KKCF (kg)	H	24	-2.119	1.550	91.8	***	***	***
	M	24	-2.088	1.483	91.8	***	***	***
	L	24	-0.552	-0.217	0.4	***	NS	NS
Leg (kg)	H	24	-0.823	0.847	97.9	***	***	***
	M	24	-0.881	0.909	98.2	***	***	***
	L	24	-0.952	1.031	90.2	***	***	***
Chump (kg)	H	24	-1.365	0.963	96.1	***	***	***
	M	24	-1.411	1.007	92.6	***	***	***
	L	24	-1.584	1.148	78.4	***	***	***
Loin (kg)	H	24	-1.385	1.063	92.4	***	***	***
	M	24	-1.443	1.111	94.8	***	***	***
	L	24	-1.529	1.176	65. 0	***	***	***

Table 1.2 (continued)

Dependent variable (y)	Treatment	n	$\log_{10} a$	Allometric coefficient (b)	R^2 (%)	Significance a	b	R^2
Best end (kg)	H	24	-1.629	1.149	93.7	***	***	***
	M	24	-1.742	1.265	96.5	***	***	***
	L	24	-1.450	0.987	80.9	***	***	***
Breast (kg)	H	24	-1.396	1.077	93.1	***	***	***
	M	24	-1.266	0.956	93.9	***	***	***
	L	24	-1.608	1.229	80.5	***	***	***
Shoulder (kg)	H	24	-0.601	0.841	98.2	***	***	***
	M	24	-0.632	0.871	96.7	***	***	***
	L	24	-0.831	1.074	94.9	***	***	***

Table 1.2 (continued)

Dependent variable (y)	Treatment	n	$\log_{10} a$	Allometric coefficient (b)	R^2 (%)	Significance		
						a	b	R^2
IMF (kg)	H	24	-2.360	1.548	95.4	***	***	***
	M	24	-2.403	1.582	90.7	**	***	***
	L	24	-1.480	0.808	26.4	**	*	*
SCF (kg)	H	24	-2.522	1.787	94.9	**	***	***
	M	24	-2.487	1.763	88.8	*	***	***
	L	24	-0.832	0.468	7.8	***	NS	NS
Total KKCF (kg)	H	24	-2.758	1.896	87.6	NS	***	***
	M	24	-2.875	1.945	91.4	NS	***	***
	L	24	0.505	-0.737	5.0	***	NS	NS
Omental fat (kg)	H	24	-2.761	1.958	88.0	NS	***	***
	M	24	-2.768	1.942	85.0	NS	***	***
	L	24	-0.293	-0.040	0.0	***	NS	NS

Table 1.3

Linearised allometric equations for the growth of body and half carcass fat depots (y) relative to the growth of the empty body (x). Equation of the form $\log_{10} y = \log_{10} a + b \log_{10} x$. Significance levels indicate the significance of the intercept and the gradient (allometric coefficient) from zero and the significance of the fit of the equation to the data (R^2).

Dependent variable (y)	Treatment	n	$\log_{10} a$	Allometric coefficient (b)	R^2 (%)	Significance a	b	R^2
Mesenteric fat (kg)†	H	18	-2.078	1.274	73.2	**	***	***
	M	18	-1.551	0.908	43.1	**	**	**
	L	12	-1.093	0.526	19.0	***	NS	NS
Visceral fat (kg)†	H	18	-2.475	1.109	40.2	NS	**	**
	M	18	-3.582	1.775	46.4	NS	**	**
	L	12	-0.645	-0.532	0.0	*	NS	NS

† Excludes treatment groups 6H/M, 12L and 18L.

Table 1.3 (continued)

Dependent variable (y)	Treatment	n	$\log_{10} a$	Allometric coefficient (b)	R^2 (%)	Significance		
						a	b	R^2
IMF (kg)	H	24	-0.622	0.821	92.0	***	***	***
	M	24	-0.617	0.842	87.6	***	***	***
	L	24	-0.538	0.610	21.2	***	*	*
SCF (kg)	H	24	-0.531	0.968	95.7	***	***	***
	M	24	-0.515	0.974	92.7	***	***	***
	L	24	-0.404	0.760	49.1	***	***	***
Total KKCF (kg)	H	24	-0.674	1.065	95.3	***	***	***
	M	24	-0.697	1.070	94.5	***	***	***
	L	24	-0.918	1.54	63.0	***	***	***
Omental fat (kg)	H	24	-0.609	1.103	96. 2	***	***	***
	M	24	-0.607	1.093	92. 2	***	***	***
	L	24	-0.728	1.408	60.7	***	***	***

Table 1.4

Linearised allometric equations for the growth of body and half carcass fat depots (y) relative to the growth of half carcass IMF, SCF, total KKCF and omental fat (x). Equation of the form $\log_{10} y = \log_{10} a + b \log_{10} x$. Significance levels indicate the significance of the intercept and the gradient (allometric coefficient) from zero and the significance of the fit of the equation to the data (R^2).

Dependent variable (y)	Significance of difference between								
	H and M			H and L			M and L		
	variances	gradients	intercepts	variances	gradients	intercepts	variances	gradients	intercepts
WCW	NS	NS	NS	NS	*	NS	NS	**	*
Total body fat†	**	NS	*						
Pelt	NS	*	NS	NS	NS	NS	NS	NS	NS
Feet	NS	NS	NS	NS	*	***	NS	NS	***
Head	NS	*	***	NS	NS	***	NS	NS	***
Heart	NS	NS	NS	NS	*	***	NS	NS	***
Lungs‡									
Liver & spleen	NS	NS	*	NS	***	NS	NS	***	NS
Kidneys	*	NS	NS	NS	*	NS	NS	***	NS

† Equation does not represent a significant proportion of the variation in the **L** data;

‡ Equation does not represent a significant proportion of the variation in the **H** and **M** data.

Table 2.1

Analysis of covariance of linearised allometric equations for the growth of body components and organs (y) relative to the growth of the empty body (x)

Dependent variable (y)	Significance of difference between								
	H and M			H and L			M and L		
	variances	gradients	intercepts	variances	gradients	intercepts	variances	gradients	intercepts
Bone	NS	NS	NS	*	NS	***	NS	NS	***
Lean	*	NS	NS	NS	***	*	NS	***	**
Carcass fat	*	NS	NS	NS	**	***	NS	**	***
IMF	NS	NS	NS	NS	NS	***	NS	NS	***
SCF	NS	NS	NS	NS	**	**	NS	*	***
KKCF†	*	NS	NS						
Leg	*	NS	*	NS	*	***	NS	NS	***
Chump	NS	NS	NS	NS	NS	NS	NS	NS	NS
Loin	**	NS	NS	NS	NS	NS	NS	NS	NS
Best end	**	NS	NS	**	NS	NS	NS	*	NS
Breast	**	NS	NS	*	NS	**	NS	*	***
Shoulder	NS	NS	NS	NS	**	NS	NS	**	*

† Equation does not represent a significant proportion of the variation in the **L** data.

Table 2.2

Analysis of covariance of linearised allometric equations for the growth of half carcass tissues and commercial joints (y) relative to the growth of the cold carcass (x)

Dependent variable (y)	Significance of difference between								
	H and M			H and L			M and L		
	variances	gradients	intercepts	variances	gradients	intercepts	variances	gradients	intercepts
IMF	NS	NS	NS	NS	**	***	NS	NS	***
SCF†	NS	NS	NS						
Total KKCF†	**	NS	NS						
Omental fat†	NS	NS	NS						
Mesenteric fat†	NS	NS	NS						
Visceral fat†	NS	NS	*						

† Equation does not represent a significant proportion of the variation in the **L** data

Table 2.3

Analysis of covariance of linearised allometric equations for the growth of body and half carcass fat depots (y) relative to the growth of the empty body (x)

	Significance of difference between								
	H and M			H and L			M and L		
Dependent variable (y)	variances	gradients	intercepts	variances	gradients	intercepts	variances	gradients	intercepts
IMF	NS	NS	NS	NS	NS	NS	NS	NS	NS
SCF	NS	NS	NS	NS	NS	*	NS	NS	NS
KKCF	*	NS	NS	NS	*	*	NS	*	*
Omental fat	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2.4

Analysis of covariance of linearised allometric equations for the growth of body and half carcass fat depots (y) relative to the growth of half carcass IMF, SCF, total KKCF and omental fat (x)

Dependent variable (y)	Treatment	n	$\log_{10} a$	Allometric coefficient (b)	R^2 (%)	Significance a	b	R^2
Fat-free	H	24	-0.787	1.340	91.0	***	***	***
carcass (kg)	M	24	-0.945	1.459	95.6	***	***	***
	L	24	-0.305	0.953	86.6	**	***	***
Total body	H	24	-2.516	2.376	86.7	***	***	***
fat (kg)†	M	24	-2.448	2.287	91.4	***	***	***
	L	24	0.324	-0.041	0.0	NS	NS	NS
Pelt (kg)‡	H	18	-0.817	1.004	91.0	***	***	***
	M	18	-0.766	0.969	84.6	***	***	***
	L	24	-0.355	0.612	18.3	NS	*	*
Feet (kg)	H	24	-1.405	0.940	94.2	***	***	***
	M	24	-1.455	0.982	90.2	***	***	***
	L	24	-1.148	0.766	68.9	***	***	***

Table 3.1

Linearised allometric equations for the growth of body components and organs (y) relative to the growth of the whole fat-free empty body (x). Equation of the form $\log_{10} y = \log_{10} a + b \log_{10} x$. Significance levels indicate the significance of the intercept and the gradient (allometric coefficient) from zero and the significance of the fit of the equation to the data (R^2).

Dependent variable (y)	Treatment	n	$\log_{10} a$	Allometric coefficient (b)	R^2 (%)	Significance a	b	R^2
Head (kg)#	H	24	-1.182	0.997	80.4	***	***	***
	M	24	-1.561	1.326	72.8	***	***	***
	L	24	-0.740	0.771	53.3	**	***	***
Heart (kg)	H	24	-2.333	1.034	90. 3	***	***	***
	M	24	-2.496	1.164	72.9	***	***	***
	L	24	-2.364	1.104	60.1	***	***	***
Lungs (kg)	H	24	-1.029	0.275	9.3	***	NS	NS
	M	24	-0.677	-0.024	0.0	*	NS	NS
	L	24	-2.462	1.346	68.9	***	***	***
Liver & spleen (kg)	H	24	-1.343	0.841	79.4	***	***	***
	M	24	-1.035	0.571	43.8	***	***	***
	L	24	-1.894	1.218	78. 8	***	***	***
Kidneys (kg)	H	24	-2.203	0.881	86.5	***	***	***
	M	23	-1.977	0.699	74.9	***	***	***
	L	24	-2.228	0.854	71.0	***	***	***

†Excludes visceral and mesenteric fat; ‡ Excludes treatment groups 24H and 24M;

includes oesophagus and trachea.

Table 3.1 (continued)

Dependent variable (y)	Treatment	n	$\log_{10} a$	Allometric coefficient (b)	R^2 (%)	Significance a	b	R^2
Bone (kg)	H	24	-0.419	0.778	73.5	***	***	***
	M	24	-0.506	0.951	81.0	***	***	***
	L	24	-0.315	0.685	59.1	***	***	***
Lean (kg)	H	24	-0.192	1.077	97.7	***	***	***
	M	24	-0.164	1.021	96.8	***	***	***
	L	24	-0.255	1.149	94.1	***	***	***
Carcass dissectible	H	24	-0.785	1.720	90.7	***	***	***
fat (kg)	M	24	-0.635	1.423	87.4	***	***	***
	L	24	-0.210	0.408	14.1	NS	*	*
IMF (kg)	H	24	-1.119	1.603	91.5	***	***	***
	M	24	-1.007	1.382	89. 4	***	***	***
	L	24	-0.687	0.541	14.7	***	**	**

Table 3.2

Linearised allometric equations for the growth of half carcass tissues and commercial joints (y) relative to the growth of half carcass lean plus bone (x). Equation of the form $\log_{10} y = \log_{10} a + b \log_{10} x$. Significance levels indicate the significance of the intercept and the gradient (allometric coefficient) from zero and the significance of the fit of the equation to the data (R^2).

Dependent variable (y)	Treatment	n	$\log_{10} a$	Allometric coefficient (b)	R^2 (%)	Significance a	b	R^2
SCF (kg)	H	24	-1.065	1.815	87.5	***	***	***
	M	24	-0.888	1.468	78.9	***	***	***
	L	24	-0.395	0.337	5.5	**	NS	NS
Left KKCF (kg)	H	24	-1.561	2.004	85.6	***	***	***
	M	24	-1.435	1.666	83.2	***	***	***
	L	24	-0.528	-0.430	0.3	*	NS	NS
Leg (kg)	H	24	-0.484	0.901	76.6	***	***	***
	M	24	-0.551	0.998	97.8	***	***	***
	L	24	-0.469	0.890	85.8	***	***	***
Chump (kg)	H	24	-1.028	0.982	75.6	***	***	***
	M	24	-1.117	1.102	89.6	***	***	***
	L	24	-1.071	1.003	77.5	***	***	***
Loin (kg)	H	24	-0.901	0.896	55.6	***	***	***
	M	24	-1.038	1.089	93.3	***	***	***
	L	24	-0.968	0.941	47. 0	***	***	***

Table 3.2 (continued)

Dependent variable (y)	Treatment	n	$\log_{10} a$	Allometric coefficient (b)	R^2 (%)	Significance a	b	R^2
Best end (kg)	H	24	-1.142	0.993	71.9	***	***	***
	M	24	-1.256	1.202	90.6	***	***	***
	L	24	-1.057	0.850	75.6	***	***	***
Breast (kg)	H	24	-0.967	0.851	51.7	***	***	***
	M	24	-0.904	0.687	61.9	***	***	***
	L	24	-1.208	1.146	67.2	***	***	***
Shoulder (kg)	H	24	-0.287	0.833	77.2	***	***	***
	M	24	-0.365	0.950	98.7	***	***	***
	L	24	-0.408	1.017	85.1	***	***	***

Table 3.2 (continued)

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Dependent variable (y)	Treatment	n	$\log_{10} a$	Allometric coefficient (b)	R^2 (%)	Significance		
						a	b	R^2
IMF (kg)	H	24	-2.843	2.065	89.8	***	***	***
	M	24	-2.792	2.014	87.9	***	***	***
	L	24	-1.230	0.662	21.0	**	*	*
SCF (kg)	H	24	-3.050	2.362	87.7	***	***	***
	M	24	-2.889	2.220	83.9	***	***	***
	L	24	-0.505	0.237	0.0	NS	NS	NS
Total KKCF (kg)	H	24	-3.274	2.472	78.6	***	***	***
	M	24	-3.336	2.462	87.4	***	***	***
	L	24	0.700	-0.926	15.3	NS	*	*
Omental fat (kg)	H	24	-3.277	2.542	78.3	***	***	***
	M	24	-3.212	2.445	80.4	***	***	***
	L	24	0.056	-0.311	0.0	NS	NS	NS

Table 3.3

Linearised allometric equations for the growth of body and half carcass fat depots (y) relative to the growth of the whole fat-free empty body (x). Equation of the form $\log_{10} y = \log_{10} a + b \log_{10} x$. Significance levels indicate the significance of the intercept and the gradient (allometric coefficient) from zero and the significance of the fit of the equation to the data (R^2).

Dependent variable (y)	Treatment	n	$\log_{10} a$	Allometric coefficient (b)	R^2 (%)	Significance a	b	R^2
Mesenteric fat (kg)†	H	18	-2.301	1.580	64.1	***	***	***
	M	18	-1.618	1.041	35.2	**	**	**
	L	12	-0.881	0.391	11.9	*	NS	NS
Visceral fat (kg)†	H	18	-2.456	1.225	26.3	**	*	*
	M	18	-3.881	2.158	43.1	***	**	**
	L	12	-0.608	-0.591	1.2	NS	NS	NS

† Excludes treatment groups 6H/M, 12L and 18L.

Table 3.3 continued

Dependent variable (y)	H and M variances	gradients	intercepts	H and L variances	gradients	intercepts	M and L variances	gradients	intercepts
	Significance of difference between								
Fat-free carcass	**	NS	NS	**	**	NS	NS	***	NS
Total body fat†#	**	NS	NS						
Pelt	NS	NS	NS	NS	NS	*	NS	NS	NS
Feet	NS	NS	NS	NS	NS	**	NS	NS	**
Head	NS	NS	**	NS	NS	***	NS	*	***
Heart	NS	NS	NS	NS	NS	**	NS	NS	**
Lungs‡									
Liver & spleen	NS	NS	**	NS	*	**	NS	**	NS
Kidneys	NS	NS	NS	NS	NS	***	NS	NS	***

† Equation does not represent a significant proportion of the variation in the **L** data;

‡ Equation does not represent a significant proportion of the variation in the **H** and **M** data;

Excludes visceral and mesenteric fat.

Table 4.1

Analysis of covariance of linearised allometric equations for the growth of body components and organs (y) relative to the growth of the fat-free empty body (x)

	H and M			H and L			M and L		
Dependent variable (y)	variances	gradients	intercepts	variances	gradients	intercepts	variances	gradients	intercepts
			Significance of difference between						
Bone	NS	NS	NS	*	NS	*	NS	NS	*
Lean	NS	NS	NS	NS	NS	*	NS	NS	*
Carcass dissectible fat	NS	NS	NS	NS	***	***	NS	***	***
IMF	NS	NS	NS	NS	***	***	NS	**	***
SCF†	NS	NS	NS						
Left KKCF†	*	NS	*						
Leg	***	NS	NS	***	NS	NS	NS	NS	*
Chump	**	NS	NS	**	NS	NS	NS	NS	NS
Loin	***	NS	NS	*	NS	NS	NS	NS	NS
Best end	***	NS	NS	***	NS	NS	NS	*	NS
Breast	**	NS	NS	**	NS	NS	NS	*	NS
Shoulder	***	NS	NS	***	NS	NS	NS	NS	NS

† Equation does not represent a significant proportion of the variation in the **L** data.

Table 4.2

Analysis of covariance of linearised allometric equations for the growth of half carcass tissues and commercial joints (y) relative to the growth of half carcass lean plus bone (x)

	Significance of difference between								
	H and M			H and L			M and L		
Dependent variable (y)	variances	gradients	intercepts	variances	gradients	intercepts	variances	gradients	intercepts
IMF	NS	NS	NS	NS	***	***	NS	***	***
SCF†	NS	NS	NS						
Total KKCF	***	NS	NS	NS	***	***	NS	***	***
Omental fat†	*	NS	NS						
Mesenteric fat†	NS	NS	NS						
Visceral fat†	NS	NS	*						

† Equation does not represent a significant proportion of the variation in the **L** data

Table 4.3

Analysis of covariance of linearised allometric equations for the growth of body and half carcass fat depots (y) relative to the growth of the fat-free empty body (x)

Dependent variable (y)	Treatment	Allometric coefficient $\log_{10} a$	(b)	R^2 (%)	Significance a	b	R^2
Leg (kg)	H	-0.452	0.954	91.0	*	***	***
	M	-0.122	0.843	90.0	NS	***	***
	L	0.039	0.791	74.1	NS	***	***
Shoulder (kg)	H	-0.265	0.959	97.2	*	***	***
	M	-0.513	1.039	95.1	**	***	***
	L	-0.279	0.959	77.0	NS	***	***
Chump (kg)	H	-1.072	0.995	59.9	NS	***	***
	M	-2.001	1.305	85.4	***	***	***
	L	-1.133	1.031	39.0	NS	**	**
Breast (kg)	H	-1.041	0.980	68.5	*	***	***
	M	-0.432	0.788	66.1	NS	***	***
	L	-1.874	1.252	61.2	**	***	***
Loin (kg)	H	-1.428	1.113	50.2	NS	***	***
	M	-1.666	1.193	61.6	*	***	***
	L	-2.184	1.366	35.2	NS	**	**
Best end (kg)	H	-1.530	1.147	83.0	***	***	***
	M	-1.210	1.046	86.5	***	***	***
	L	-1.431	1.121	50.7	NS	***	***

Table 5.1

Linearised allometric equations for the growth of bone in each commercial joint (y) relative to the growth of the total weight of bone in the dissected half carcass (x). Equations of the form $\log_{10} y = \log_{10} a + b \log_{10} x$. Significance levels indicate the significance of the intercept and the gradient (allometric coefficient) from zero and the significance of the fit of the equation to the data (R^2).

Dependent variable (y)	Treatment	$\log_{10} a$	Allometric coefficient (b)	R^2 (%)	Significance a	b	R^2
Leg (kg)	H	-0.498	0.986	97.9	***	***	***
	M	-0.577	1.009	97.4	***	***	***
	L	-0.137	0.889	92.2	NS	***	***
Shoulder (kg)	H	-0.198	0.938	97.6	NS	***	***
	M	-0.182	0.933	96.0	NS	***	***
	L	-0.769	1.104	94.9	***	***	***
Chump (kg)	H	-1.129	1.019	93.6	***	***	***
	M	-1.201	1.037	84.8	**	***	***
	L	-0.924	0.945	73.2	*	***	***
Breast (kg)	H	-1.395	1.077	82.6	**	***	***
	M	-0.748	0.886	47.7	NS	***	***
	L	-1.987	1.238	63.1	**	***	***
Loin (kg)	H	-1.218	1.069	86.9	**	***	***
	M	-1.236	1.074	89.9	***	***	***
	L	-0.603	0.885	63.7	NS	***	***
Best end (kg)	H	-1.691	1.131	85.5	***	***	***
	M	-2.233	1.297	84.9	***	***	***
	L	-1.156	0.976	74.2	*	***	***

Table 5.2

Linearised allometric equations for the growth of lean in each commercial joint (y) relative to the growth of the total weight of lean in the dissected half carcass (x). Equations of the form $\log_{10} y = \log_{10} a + b \log_{10} x$. Significance levels indicate the significance of the intercept and the gradient (allometric coefficient) from zero and the significance of the fit of the equation to the data (R^2).

Dependent variable (y)	Treatment	Allometric coefficient $\log_{10} a$	(b)	R^2 (%)	Significance a	b	R^2
Leg (kg)	H	-0.698	0.950	95.7	***	***	***
	M	-0.736	0.966	85.8	*	***	***
	L	-0.778	1.013	49.7	NS	***	***
Shoulder (kg)	H	-0.086	0.889	99.1	NS	***	***
	M	0.094	0.829	98.0	NS	***	***
	L	-0.432	0.998	79.3	NS	***	***
Chump (kg)	H	-0.965	0.971	93.7	***	***	***
	M	-1.017	0.986	82.9	**	***	***
	L	-0.780	0.890	41.7	NS	***	***
Breast (kg)	H	-0.928	1.057	96.9	***	***	***
	M	-0.343	0.854	29.1	NS	**	**
	L	-0.793	1.018	90.2	**	***	***
Loin (kg)	H	-1.322	1.126	97.2	***	***	***
	M	-1.773	1.262	92.7	***	***	***
	L	-2.010	1.330	56.4	*	***	***
Best end (kg)	H	-1.693	1.220	97.6	***	***	***
	M	-2.003	1.324	96.4	***	***	***
	L	-1.525	1.176	71.7	**	***	***

Table 5.3

Linearised allometric equations for the growth of total dissectible fat in each commercial joint (y) relative to the growth of the total weight of total dissectible fat in the dissected half carcass (x). Equations of the form $\log_{10} y = \log_{10} a + b \log_{10} x$. Significance levels indicate the significance of the intercept and the gradient (allometric coefficient) from zero and the significance of the fit of the equation to the data (R^2).

| Dependent variable (y) | Treatment | Allometric coefficient | | R^2(%) | Significance | | |
		log$_{10}$ a	(b)		a	b	R^2
Leg (kg)	H	0.107	0.620	60.7	NS	***	***
	M	0.159	0.602	28.7	NS	**	**
	L	-1.010	1.080	47.3	NS	***	***
Shoulder (kg)	H	-0.537	1.045	97.4	***	***	***
	M	-0.566	1.052	90.6	*	***	***
	L	-0.175	0.926	72.2	NS	***	***
Chump (kg)	H	-0.220	0.692	65.9	NS	***	***
	M	-0.192	0.684	49.2	NS	***	***
	L	-0.056	0.610	22.4	NS	*	*
Breast (kg)	H	-0.889	1.044	83.6	**	***	***
	M	-1.068	1.104	72.3	*	***	***
	L	-0.467	0.850	42.1	NS	***	***
Loin (kg)	H	-0.944	1.002	75.2	*	***	***
	M	-1.079	1.056	73.0	**	***	***
	L	-1.640	1.220	41.8	*	***	***
Best end (kg)	H	-2.040	1.373	96.0	***	***	***
	M	-2.044	1.385	90.5	***	***	***
	L	-3.240	1.810	60.3	**	***	***

Table 5.4

Linearised allometric equations for the growth of IMF in each commercial joint (y) relative to the growth of the total weight of IMF in the dissected half carcass (x). Equations of the form $\log_{10} y = \log_{10} a + b \log_{10} x$. Significance levels indicate the significance of the intercept and the gradient (allometric coefficient) from zero and the significance of the fit of the equation to the data (R^2).

| Dependent variable (y) | Treatment | Allometric coefficient | | R² (%) | Significance | | |
		$\log_{10} a$	(b)		a	b	R²
Leg (kg)	H	-0.899	1.031	96.2	***	***	***
	M	-0.979	1.064	92.3	***	***	***
	L	-1.130	1.140	29.3	NS	**	**
Shoulder (kg)	H	0.144	0.796	96.8	NS	***	***
	M	0.374	0.710	82.0	NS	***	***
	L	0.308	0.713	33.7	NS	**	**
Chump (kg)	H	-1.328	1.091	94.9	***	***	***
	M	-1.426	1.124	86.8	***	***	***
	L	-2.050	1.320	56.9	**	***	***
Breast (kg)	H	-1.174	1.136	93.5	***	***	***
	M	-0.985	1.085	81.2	**	***	***
	L	-1.010	1.090	39.6	NS	**	**
Loin (kg)	H	-1.440	1.174	95.8	***	***	***
	M	-1.879	1.314	92.9	***	***	***
	L	-2.570	1.560	50.2	**	***	***
Best end (kg)	H	-1.511	1.171	96.5	***	***	***
	M	-2.011	1.348	95.3	***	***	***
	L	-1.530	1.210	59.2	*	***	***

Table 5.5

Linearised allometric equations for the growth of SCF in each commercial joint (y) relative to the growth of the total weight of SCF in the dissected half carcass (x). Equations of the form $\log_{10} y = \log_{10} a + b \log_{10} x$. Significance levels indicate the significance of the intercept and the gradient (allometric coefficient) from zero and the significance of the fit of the equation to the data (R^2).

Dependent variable (y)	Significance of difference between								
	H and M			H and L			M and L		
	variances	gradients	intercepts	variances	gradients	intercepts	variances	gradients	intercepts
Leg	NS	NS	NS	NS	NS	NS	NS	NS	NS
Shoulder	NS	NS	NS	NS	NS	NS	NS	NS	NS
Chump	**	NS	NS	NS	NS	NS	NS	NS	NS
Breast	NS	NS	NS	NS	NS	NS	NS	NS	NS
Loin	NS	NS	NS	NS	NS	NS	NS	NS	NS
Best end	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 6.1

Analysis of covariance of linearised allometric equations for the growth of bone in each commercial joint (y) relative to the growth of the total weight of bone in the dissected half carcass (x)

	Significance of difference between								
	H and M			H and L			M and L		
Dependent variable (y)	variances	gradients	intercepts	variances	gradients	intercepts	variances	gradients	intercepts
Leg	NS	NS	NS	NS	NS	**	NS	NS	**
Shoulder	NS	NS	NS	NS	*	NS	NS	*	NS
Chump	NS	NS	NS	NS	NS	**	NS	NS	*
Breast	NS	NS	NS	NS	NS	NS	NS	NS	NS
Loin	*	NS	NS	NS	NS	NS	NS	NS	NS
Best end	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 6.2

Analysis of covariance of linearised allometric equations for the growth of lean in each commercial joint (y) relative to the growth of the total weight of lean in the dissected half carcass (x)

Dependent variable (y)	H and M			H and L			M and L		
	variances	gradients	intercepts	variances	gradients	intercepts	variances	gradients	intercepts
Leg	NS	NS	NS	NS	NS	***	NS	NS	***
Shoulder	NS	NS	*	NS	NS	NS	NS	NS	NS
Chump	NS	NS	NS	NS	NS	*	NS	NS	NS
Breast	NS	NS	NS	NS	NS	NS	NS	NS	NS
Loin	NS	NS	NS	NS	NS	*	NS	NS	NS
Best end	NS	NS	*	NS	NS	NS	NS	NS	NS

The header "Significance of difference between" spans the H and M, H and L, and M and L column groups.

Table 6.3

Analysis of covariance of linearised allometric equations for the growth of total dissectible fat in each commercial joint (y) relative to the growth of the total weight of total dissectible fat in the dissected half carcass (x)

| Dependent variable (y) | Significance of difference between | | | | | | | | |
| | H and M | | | H and L | | | M and L | | |
	variances	gradients	intercepts	variances	gradients	intercepts	variances	gradients	intercepts
Leg	NS	NS	NS	NS	NS	*	NS	NS	*
Shoulder	NS	NS	NS	NS	NS	*	NS	NS	*
Chump	NS	NS	NS	NS	NS	NS	NS	NS	NS
Breast	NS	NS	NS	NS	NS	*	NS	NS	*
Loin	NS	NS	NS	NS	NS	*	NS	NS	**
Best end	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 6.4

Analysis of covariance of linearised allometric equations for the growth of IMF in each commercial joint (y) relative to the growth of the total weight of IMF in the dissected half carcass (x)

Dependent variable (y)	Significance of difference between								
	H and M			H and L			M and L		
	variances	gradients	intercepts	variances	gradients	intercepts	variances	gradients	intercepts
Leg	NS	NS	NS	NS	NS	NS	NS	NS	NS
Shoulder	NS	NS	NS	NS	NS	**	NS	NS	*
Chump	NS	NS	NS	NS	NS	*	NS	NS	NS
Breast	NS	NS	NS	NS	NS	NS	NS	NS	NS
Loin	NS	NS	NS	NS	NS	NS	NS	NS	NS
Best end	NS	*	NS	NS	NS	*	NS	NS	**

Table 6.5

Analysis of covariance of linearised allometric equations for the growth of SCF in each commercial joint (y) relative to the growth of the total weight of SCF in the dissected half carcass (x)

Appendix III

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Sampling age (months)	Treatment group	Fleece weight (kg)		Fleece growth rate (g/day)		Staple length (mm)		Increase in length (mm/day)		Fibre diameter (µm)	
6	6H/M	0.800	(0.11)	4.82	(0.66)	130.67	(3.48)	0.787	(0.02)	21.82	(2.27)
	12H	0.945	(0.23)	5.69	(1.37)	148.67	(13.45)	0.895	(0.08)	21.59	(2.60)
	18H	0.860	(0.19)	5.18	(1.17)	158.17	(19.15)	0.953	(0.12)	22.13	(2.20)
	24H	0.843	(0.28)	5.08	(1.67)	143.08	(16.41)	0.863	(0.10)	18.97	(3.55)
	Mean	**0.862**	**(0.20)**	**5.19**	**(1.23)**	**145.15**	**(16.84)**	**0.875**	**(0.10)**	**21.13**	**(2.83)**
12	12H	2.066	(0.20)	12.37	(1.22)	147.67	(3.91)	0.880	(0.02)	24.19	(2.34)
	18H	1.898	(0.30)	11.36	(1.80)	155.00	(14.88)	0.922	(0.09)	26.58	(3.89)
	24H	1.844	(0.38)	11.04	(2.27)	142.17	(16.51)	0.847	(0.10)	24.82	(2.52)
	Mean	**1.936**	**(0.30)**	**11.59**	**(1.80)**	**148.28**	**(13.37)**	**0.883**	**(0.08)**	**25.20**	**(3.00)**
18	18H	3.272	(0.59)	16.78	(3.02)	176.33	(8.96)	0.900	(0.04)	30.28	(3.69)
	24H	2.806	(0.43)	14.39	(2.20)	167.50	(16.55)	0.852	(0.08)	27.79	(3.29)
	Mean	**3.039**	**(0.55)**	**15.59**	**(2.81)**	**171.92**	**(13.50)**	**0.876**	**(0.07)**	**29.03**	**(3.58)**
24	24H	2.765	(0.35)	14.63	(1.86)	135.90	(13.39)†	0.718	(0.07)	27.09	(2.40)
	Total	**1.810**	**(0.94)**	**10.13**	**(4.69)**	**151.02**	**(18.36)**	**0.867**	**(0.09)**	**24.53**	**(4.27)**

No significant differences between means within each age group; † n = 4

Table 7.1

Mean fibre characteristics of British Angora wether goats reared from six to 24 months of age on a high plane of nutrition; mean of six goats (S.D.)

Sampling age (months)	Treatment group	Fleece weight (kg)		Fleece growth rate (g/day)		Staple length (mm)		Increase in length (mm/day)		Fibre diameter (µm)	
6	6H/M	0.800	(0.11)	4.82	(0.66)	130.67	(3.48)	0.787	(0.02)	21.82	(2.27)
	12M	0.938	(0.26)	5.65	(1.55)	150.58	(23.42)	0.908	(0.14)	20.45	(2.65)
	18M	0.837	(0.18)	5.04	(1.07)	151.75	(14.33)	0.915	(0.09)	20.03	(2.80)
	24M	0.967	(0.21)	5.83	(1.26)	158.50	(14.31)	0.957	(0.09)	21.58	(1.98)
	Mean	**0.885**	**(0.20)**	**5.33**	**(1.18)**	**147.88**	**(17.98)**	**0.892**	**(0.11)**	**20.97**	**(2.41)**
12	12M	1.710	(0.18)	10.24	(1.09)	147.42	(12.55)	0.877	(0.07)	22.45	(1.18)
	18M	1.564	(0.27)	9.37	(1.64)	148.58	(6.46)	0.885	(0.04)	21.35	(2.52)
	24M	1.430	(0.43)	8.56	(2.60)	147.90	(13.95)‡	0.878	(0.08)	21.74	(1.57)
	Mean	**1.568**	**(0.32)**	**9.39**	**(1.90)**	**147.97**	**(10.54)**	**0.880**	**(0.06)**	**21.85**	**(1.80)**
18	18M	2.668	(0.71)	13.68	(3.63)	158.25	(12.41)	0.808	(0.06)	23.80	(2.20)
	24M	2.895	(0.46)	14.84	(2.34)	161.75	(12.12)†	0.823	(0.06)	23.43	(3.18)
	Mean	**2.781**	**(0.58)**	**14.26**	**(2.97)**	**159.65**	**(11.73)**	**0.814**	**(0.06)**	**23.62**	**(2.61)**
24	24M	1.998	(0.41)	10.57	(2.18)	138.00	(12.23)‡	0.728	(0.06)	26.09	(3.93)
	Total	**1.581**	**(0.79)**	**8.86**	**(3.87)**	**149.13**	**(15.29)**	**0.860**	**(0.10)**	**22.27**	**(2.89)**

No significant differences between means within each age group; † n = 4; ‡ n = 5

Table 7.2

Mean fibre characteristics of Angora wether goats reared from six to 24 months of age on a medium plane of nutrition; mean of six goats (S.D.)

Sampling age (months)	Treatment group	Fibre diameter (µm)	
6	6L	25.27	(3.35)
12	12L	29.06	(1.86)
	18L	28.08	(2.65)
	24L	25.74	(2.29)
	Mean	**27.63**	**(2.58)**
18	18L	25.11[a]	(1.69)
	24L	21.97[b]	(2.58)
	Mean	**23.54**	**(2.65)**
24	24L	29.41	(5.52)
	Total	**26.38**	**(3.79)**

Means with different superscripts within each age group differ significantly ($P < 0.05$)

Table 7.3

Mean fibre diameter of British Angora wether goats reared from six to 24 months of age on a low plane of nutrition; mean of six goats (S.D.)

Appendix IV

	Treatment group										
	High				Medium			Low			
	6H/M	12H	18H	24H	12M	18M	24M	6L	12L	18L	24L
Back fat thickness											
C (mm)	1.7	2.2	5.6	3.3*	1.5	2.8	2.0†	0.6	0.8	0.8	1.1
	(1.2)	(0.8)	(2.8)	(1.5)	(0.5)	(1.4)		(0.2)	(0.5)	(0.2)	(0.4)
D (mm)	3.7	4.8	8.2	5.5*	4.0	4.3	6.0†	1.4‡	1.6	1.1	1.5
	(1.0)	(1.2)	(4.5)	(2.2)	(0.7)	(1.0)		(0.5)	(0.7)	(0.3)	(0.4)
(C + D) / 2 (mm)	2.7	3.5	6.9	4.4*	2.7	3.5	4.0†	1.0‡	1.2	1.0	1.2
	(1.0)	(0.9)	(3.1)	(1.8)	(0.6)	(1.0)		(0.2)	(0.5)	(0.2)	(0.4)
Eye muscle area	5.56	9.30	11.16	13.18	6.95	8.38	11.79#	6.29	6.89	5.77	7.93
(cm^2)	(1.70)	(1.73)	(1.87)	(3.30)	(1.15)	(1.73)	(2.77)	(1.19)	(1.26)	(0.79)	(1.48)
F - T (mm)	82.5	85.0	71.7	105.8	85.8	75.0	91.7	80.8	91.7	90.8	102.5
	(12.9)	(8.4)	(8.8)	(36.7)	(13.2)	(15.2)	(7.5)	(3.8)	(8.8)	(6.7)	(6.9)

† n = 1; * n = 3; ‡ n = 4; # n = 5

Mean back fat thickness, eye muscle area and upper leg length measurements of British Angora wether goats reared from six to 24 months of age on a high, medium or low plane of nutrition - mean (s.d.) of six goats unless otherwise indicated

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