INFLUENCE OF NUTRITION AND BODY COMPOSITION ON

MILK PRODUCTION IN THE GRAZING EWE

A thesis

Submitted in partial fulfilment

of the requirements for the degree

of

Doctor of Philosophy

in the

University of Canterbury

by

Kennett Gordon Geenty

Lincoln College

1983

Abstract of a thesis submitted in partial fulfilment of the requirements for the Degree of Doctor of Philosophy

INFLUENCE OF NUTRITION AND BODY COMPOSITION ON MILK PRODUCTION IN THE GRAZING EWE

by

K.G. Geenty

Two experiments were conducted to examine the interrelationships between body composition at parturition, herbage allowance during lactation and milk production. Detailed measurements of feed intake and changes in body composition allowed estimates of maintenance energy requirement and efficiency of use of energy for milk production.

Dorset ewes were offered low (L-) or high (H-) herbage allowances during pregnancy to achieve post-partum body weights, respectively, of about 50 and 60-65 kg. During the first 6 weeks of lactation herbage allowances were approximately 2 (-L), 5 (-M and -Mm) and 8 (-H) kg DM/ewe/d and feed intake was determined using chromic oxide dilution. In the first experiment (Expt.A) ewes were machine-milked and in the second (Expt.B) they were suckled by twin lambs with a further group (-Mm) machine-milked. Samples of ewes were slaughtered during early pregnancy, post-partum, and after 6 weeks of lactation.

Body weight differences post-partum between L- and H- groups were 10 and 15 kg in Expts.A and B respectively. During lactation body weight changes appeared erratic, particularly in Expt.B, owing to the effects of variation in gut fill.

Daily feed intake of machine-milked ewes on -M and -H allowances reached a maximum (1.9-2.2 kg OM/ewe/d) 2-3 weeks after parturition but ewes rearing lambs on similar allowances showed maximum intake (2.5-2.8 kg OM/ewe/d) during the first week. Mean intakes during lactation were 58, 69 and 73 g DOM/kg $W^{.75}$/d respectively for -L, -M and -H groups machine-milked and 51, 75 and 83 g DOM/kg $W^{.75}$/d respectively for -L, -M and -H groups rearing twin lambs. In both experiments ewes in L- groups had approximately 14% greater mean intake (g DOM/kg $W^{.75}$/d) during lactation compared with those in H- groups. Mean daily milk production of ewes rearing lambs was 2.0, 2.5 and 2.7 kg/d respectively in -L, -M and -H groups and was 33-52% greater than that for machine-milked ewes offered similar herbage allowances. In both experiments L- ewes had 14% greater milk yield (g/kg $W^{.75}$/d) compared with H- ewes. Mean lamb growth rates in Expt.B averaged 209, 254 and 268 g/lamb/d in -L, -M and -H groups, respectively. Lambs in the H- group were approximately 11% heavier at birth than those in the L- group and their mean growth rate was 20 g/d greater.

Body fat and energy content of live ewes at the start of lactation was predicted using regression relationships from ewes slaughtered post-partum. There was large variation in the energy content of body weight loss during lactation (-37 to +140 MJ/kg) owing to variation in weight of gut fill and changes in chemical

composition of the empty body.

In Expt.A the body fat content of ewes during early pregnancy was 16.9 kg. Predicted values post-partum were 10.0 and 15.7 kg in L- and H- groups, respectively. During lactation all groups showed body fat losses which ranged from 53 (LH) to 120 g/d (HL). Body fat content during early pregnancy in Expt.B was slightly greater (19.0 kg) than in Expt.A and predicted values post-partum were 11.5 (L-) and 19.7 kg (H-). Fat mobilization during lactation was greater than in Expt.A, and ranged from 157 (LH) to 287 g/d (HL). In both experiments there were losses in body protein during pregnancy in L- ewes (5 and 15 g/d in Expts.A and B respectively). During lactation, protein losses were most evident in H- ewes, being greatest in HL groups (26 and 43 g/d in Expts.A and B respectively). Water:protein ratio in the empty body showed a progressive increase during pregnancy and lactation in both experiments.

Estimated maintenance energy requirement for machine-milked ewes tended to be greater for H- (.236 MJ ME/kg W/d) compared with L- ewes (.205 MJ ME/kg W/d) but was similar for both groups of ewe rearing lambs (average of .238 MJ ME/kg W/d). Efficiency of use of ME above maintenance for milk production (K_1) in L- and H- groups was, respectively, .69 and .95 in machine-milked, and .69 and .64 in suckled ewes. Energy from mobilized body tissues was utilized for milk production with respective efficiencies in L- and H- ewes of .23 and .35 in machine-milked, and .40 and .50 in suckled ewes. Efficiency of conversion of total energy available (i.e. ME above maintenance and mobilized tissue energy) to milk energy ($K_{1(t)}$), when compared among all groups in both

experiments, tended to decrease (from .84 to .51) with increasing body energy mobilization. There was a positive relationship, however, between $K_{1(t)}$ and the proportion of mobilized energy derived from body protein.

Metabolizable energy intakes in the present experiments appeared to be 10-15% greater than calculated requirements from ARC (1980). Estimates of ME requirements for lactating ewes at pasture, in relation to body weight, level of milk production and body energy change, have been calculated based on the present data.

CONTENTS

List of Tables

List of Figures

List of Abbreviations

Nutritional treatments.

L-	low herbage allowance during pregnancy
H-	high " · " " "
-L	low herbage allowance during lactation
-M	medium " " " "
-Mm	" " " " " (machine-milked group in Expt.B)
-H	high herbage allowance during lactation (individual treatments denoted by various combinations)

Nutritive value of feeds.

DM	dry-matter
OM	organic-matter
D	digestibility
DMD	dry-matter digestibility
OMD	organic-matter digestibility
CP	crude protein

Feed intake.

O/F	oesophageally fistulated
FO	faecal output
DMI	dry-matter intake
OMI	organic-matter intake
DDMI	digestible dry-matter intake
DOMI	digestible organic-matter intake

Body weight and composition.

W   body weight

MBW   metabolic body weight ($W^{.75}$)

EBW   empty body weight (i.e. fasted body weight less contents of the alimentary tract)

MEBW   metabolic empty body weight ($EBW^{.75}$)

FFEBW   fat-free empty body weight

Energy metabolism.

GE   gross energy

FE   faecal energy

DE   digestible energy

ME   metabolizable energy

DEI   digestible energy intake

MEI   metabolizable energy intake

MEm   body maintenance energy requirement (i.e. ME required at zero body energy balance)

MKE   milk energy

TSE   body tissue energy

K_1 efficiency of utilization of ME above maintenance for milk production

$K_{1(t)}$ efficiency of utilization of total energy available (i.e. ME above maintenance and mobilized tissue energy) for milk production

Statistical.

SD   standard deviation

RSD   residual standard deviation

CV	coefficient of variation
r	correlation coefficient
r^2	coefficient of variation (simple regression)
R^2	coefficient of variation (multiple regression)

1. INTRODUCTION

Increasing prolificacy in the national sheep flock means that high milk production becomes increasingly important to ensure viability and high growth rates in lambs. Achievement of optimum milk production requires knowledge of maintenance energy requirement of the ewe, of her capacity to convert dietary energy above maintenance directly to milk energy and her ability to store surplus food energy as body reserves then to utilize these during feed shortage for foetal growth or milk production.

Studies with the ewe at pasture or indoors have shown positive relationships between food intake and milk production. However, estimates of the efficiency with which ME consumed above maintenance is used for milk production have varied from .59 in ewes at pasture (Maxwell et al., 1979) to .90 on a conserved forage-concentrate diet (Gardner and Hogue, 1966). Comparable values in the dairy cow vary little from .63 (Moe and Tyrrell, 1975).

Estimates of maintenance requirement of the lactating ewe at pasture are scarce. Determination of both maintenance energy requirement and efficiency of milk synthesis (Maxwell et al.,1979; Langlands, 1977) have involved assessment of body energy change from live body weight. The small amount of comparative slaughter data available for the lactating ewe, however, have shown high variability of the energy content of body weight change (Cowan et al., 1980a), thus questioning the accuracy of these estimates.

Indoor experiments have shown that feeding ewes during pregnancy to achieve greater body weight at parturition has not increased milk production during early lactation (Peart, 1970; Stern et al., 1978). A negative relationship was suggested by Stern et al (1978) to result from depression of intake as a consequence of increased body fat. Moreover, there is evidence that fat reserves may be used for milk synthesis with a relatively low efficiency in the ewe (Cowan et al., 1980a) compared with the dairy cow (Moe et al., 1971).

Hence there is not only a lack of direct estimates of energy utilization in the lactating ewe but suggestions of large variation in energetic efficiency of milk production. Moreover, such information for the lactating ewe at pasture is scarce.

Chapters 2-8 of this thesis review the available literature on energy requirements, body composition, feed intake and milk production in the ewe. In Chapter 9 two experiments are described which measure the influence of feed intake and differences in body composition on partitioning of energy and efficiency of milk production in the grazing ewe.

2. ENERGY UTILIZATION IN THE EWE - A REVIEW

2.1 Feeding systems.

The central importance of energy to production in ruminants has necessitated detailed quantification both of the availability of energy in feeds and energy requirements of the animal. Early feeding systems were based on the Starch Equivalent (SE) and Total Digestible Nutrient (TDN) systems. Despite their widespread use in the U.K. and U.S.A. respectively, these systems were inflexible in allowing for variation in energy use with different types of feeds, level of feeding and physiological status of the animal.

In recent years more sophisticated systems have been devised. These have included the Metabolizable Energy (ME) system (Blaxter, 1962), the Californian Net Energy System (Lofgreen and Garrett, 1968), the East German Net Energy (fattening) System (Schiemann et al., 1971) and the Net Energy (lactation) System (Flatt et al., 1968, 1972). The first of these has been adopted in New Zealand.

2.2 The ME feeding system.

2.2.1 Characterisation of the feed.

Feeds are characterised in terms of gross energy (GE), digested energy (DE) and energy available for metabolism (ME) as follows -

(1) DE = GE - faecal energy

(2) ME = DE - [urinary energy + methane energy]

Gross energy of feeds, faeces and urine are obtained as
their heat of combustion in oxygen by bomb calorimetry.
The ME content of feeds is expressed per kg of DM (M/D)
estimated at maintenance. Energy changes in the animal
can be estimated by direct calorimetry (heat flow),
indirect calorimetry (gaseous exchange) carbon and
nitrogen balances or comparative slaughter. The latter,
which is more appropriate in grazing studies, is
considered to approach the accuracy of calorimetry
(Blaxter, 1962).

2.2.2 <u>Feeding level and metabolizability.</u>
Digestibility declines as level of feeding increase from
maintenance (Brown, 1966; Blaxter <u>et al</u> 1966; Blaxter, 1969),
the extent increasing with decreasing D of the feed. For
example, D value of feeds declines from .75 to .73 and
from .55 to .51 between maintenance and 2X maintenance
levels of feeding (Blaxter, 1969; ARC, 1980).

The metabolizability (q) of a feed (ME/GE)
indicates the proportion of gross energy available for
metabolism. As feeding level increases, proportional
energy loss through fermentation (methane) and urine
decline (Blaxter, 1969; Schiemann <u>et al</u>., 1971) which
tends to negate the corresponding increases in faecal
energy losses. Blaxter (1969) derived a relationship
which implies that only when q is below .62 (i.e. with
poor quality diets) at maintenance will metabolizability
fall with increased feeding level.

2.3 <u>Characterization of energy requirements of sheep.</u>

2.3.1 <u>Maintenance.</u> The basal metabolic rate of animals (heat production/kg W) decreases with increasing weight but is relatively constant in relation to body surface area (Rubner, 1888). Rubner's surface area law, determined in dogs, was found to apply between animal species but difficulty in measuring body surface area led to the use of power functions of body weight. Brody (1945) showed that species varying in size from mice to elephants had a relatively constant fasting metabolism of .295 MJ/kg $W^{.73}$ Kleiber <u>et al</u> (1945) suggested use of the .75 power of body weight. The concept of metabolic body weight has since been used extensively with recognition that different exponents will give best precision in different circumstances.

Components of energy requirement for maintenance include that for fasting heat production, digestion and metabolism, regulation of homeothermy and muscular work. Fasting metabolism, per kg of metabolic body weight, in the adult ewe is relatively constant at .220-.226 MJ/d (Blaxter, <u>et al</u>. 1966; Graham <u>et al</u>. 1974) but requirements for thermoregulation and muscular work vary widely according to the environment (ARC, 1980). The energy cost of wool production is frequently included with maintenance but is considered to form a relatively insignificant proportion (Yeates <u>et al</u>.,1975).

The efficiency with which ME is used for maintenance varies with dietary quality. Estimates range from .64 to .75 for q values of .40-.70 (ARC, 1980).

Estimates of MEm for adult sheep indoors range from .382-.498 MJ ME/kg $W^{.75}$ (Coop, 1962; Langlands <u>et al</u>., 1963a). Comparisons between sheep penned indoors and

those grazing have shown 24 to 70% greater requirement outdoors (Langlands et al., 1963b; Young and Corbett, 1972). Values for grazing non-pregnant non-lactating adult sheep have varied from .517 to .598 MJ ME/kg $W^{.75}$/d (Lambourne and Reardon, 1963; Langlands et al., 1963b) and in lactating ewes from .548 to .726 MJ ME/kg $W^{.75}$/d (Langlands, 1977; Maxwell et al., 1979).

2.3.2 Pregnancy.

Estimates of the efficiency of utilization of energy (ME and mobilized body energy) for growth of the conceptus have varied little from .13 in comparative slaughter (Sykes and Field, 1972; Rattray et al., 1973,1974a; Robinson et al., 1980) and calorimetric (Graham, 1964) studies. This indicates a requirement of 7.5 joules per joule of energy deposited in the conceptus.

2.3.3 Lactation.

2.3.3.1 Partitioning of energy. The lactating ruminant is often in negative energy balance during early lactation with replenishment of body energy reserves occuring later in lactation and after weaning. There is, however, a lack of information on the way in which the lactating ewe partitions energy for milk production from dietary and body sources.

This partitioning of energy can be done statistically in calorimetric or comparative slaughter experiments, or using body weight as an indirect measure of body energy change. An example is the following multiple regression model used by Moe et al (1971) in large scale calorimetric studies with lactating dairy cows

$$MEI = b1MBW + b2MKE + b3TSE(gain) + b4TSE(loss) + a$$

In this equation b1 gives maintenance requirement (MJ/kg $W^{.75}$), 1/b2 the efficiency of utilization of ME above maintenance for milk production (K_1), 1/b3 the efficiency of body energy gain (K_f) from ME intake and b4/b2 gives the efficiency with which body energy reserves are utilized for milk production. The energy unaccounted for, indicated by the intercept (a), was allocated to maintenance (a/MBW). An alternative approach is to constrain regressions through the origin so any unexplained energy is proportionately assigned to the "independant" variables (Hoffman et al., 1974; Langlands, 1977; Maxwell et al.,1979).

2.3.3.2 Efficiency of milk production. Many studies on energy utilization in the lactating ewe have used insufficient numbers for regression analysis and efficiency has been derived from group means and energy balance with assumptions made about MEm and efficiency of utilization of body energy reserves. Values obtained in this way have included .66 and .82 respectively for single- and twin-suckled ewes (Gardner and Hogue, 1964) and .53-.80 for ewes on different nutritional treatments (Cowan et al.,1980a). Other studies have used multiple regression with theoretical estimates of body energy change based on body weight change and have provided K_1 values of .66 (Langlands, 1977) and .59 (Maxwell etal.,1979). Re-analysis by Robinson (1978) of data from several studies, with theoretical adjustments for body

energy change, gave an average efficiency of .63.

2.3.3.3 <u>Body energy utilization or deposition.</u>
Experiments using dietary supplementation with protein
(Robinson <u>et al</u>.,1979; Cowan <u>et al</u>.,1981) have shown
increased utilization of body fat reserves and greater
milk production in the ewe at low energy intake. Gonzalez
<u>et al</u> (1982) suggested that milk yield response to protein
supplementation was not due solely to increased tissue
energy loss, but possibly to an effect of protein
absorbtion on efficiency. Comparative slaughter data of
Cowan <u>et al</u> (1980a) suggest that body fat reserves are
utilized for milk production with an efficiency of less
than .50. This compares with estimates of .82-.86 in the
dairy cow (Moe and Flatt, 1969; Moe <u>et al</u>.,1971).

Estimates of efficiency of use of dietary ME for
tissue energy gain (K_f) in the lactating ewe include
values of .60 (Graham, 1964) and .53 (Maxwell <u>et</u>
<u>al</u>.,1979). Values for K_f in lactating goats (Armstrong
and Blaxter, 1965) and dairy cows (Moe <u>et al</u>.,1971) have
tended to be greater than in non-lactating
contemporaries (.75 compared with .58 in the cow). It has
been suggested this is due to improved efficiency of
lipogenesis with removal of acetate by the mammary gland
for milk synthesis.

3. BODY COMPOSITION OF THE EWE - A REVIEW

The ability of the ewe to accumulate body energy reserves through fat and protein deposition and to mobilize these reserves for foetal growth or milk production is of considerable practical importance. Measurement of body energy change during lactation is necessary for precise determination of energetic efficiency of milk production.

3.1. Effects of body weight loss and recovery on body composition.

Body weight fluctuation in both growing and adult sheep has had varying influences on changes in body composition.

Burton et al (1974) compared changes in body composition of young ewes showing uninterrupted or interrupted growth between 40 and 71 kg. Allometric growth coefficients suggested a proportionately greater change of body fat during weight loss than during weight gain while water and protein increased relatively faster during recovery. It was concluded that although the mechanism is not clear, less lipid is deposited in fat cells during regrowth than during normal growth.

Greater rates of protein and lower rates of fat deposition during realimentation have been reported in other studies with growing sheep (Reid et al., 1968; Drew and Reid, 1975; Little and Sandland, 1975) while some experiments have shown no difference compared with sheep showing uninterrupted growth (Searle and Graham, 1975; Thornton et al., 1979). Varying results have also been

reported with mature sheep. Keenan et al (1969) showed that mature Merino wethers regained only 75% of previous energy reserves when realimented to the same body weight as controls while Thornton et al (1969) showed complete recovery of depleted fat reserves on weight regain.

Ewes grazing hill pastures may be unable to replace body fat reserves severely depleted during late pregnancy and early lactation, despite subsequent recovery of body weight and protein content (Field et al.,1968; Sykes et al.,1974). Severe undernutrition of non-pregnant ewes (Hight and Barton,1965) was associated with only moderate body fat depletion and lack of recovery of body weight and fat reserves on realimentation. This was attributed to a hypometabolic state associated with markedly reduced weights of thyroid glands.

It appears, then, that both juvenile and mature sheep subjected to restricted nutrition may show an impaired ability to fully replace depleted body fat reserves. There may be a priority for protein deposition during weight recovery. In the limited evidence with the lactating ewe the phenomenon was associated with severe undernutrition and and virtual complete depletion of body fat reserves.

3.2 Changes in body composition during pregnancy.

Maternal body weight loss and changes in body composition during pregnancy are influenced by environment, level of feeding and number of foetuses carried. Ewes subjected to undernutrition indoors may lose up to 86% of total body fat (Russel et al.,1968; Sykes and Field, 1972; Lodge and Heaney, 1973) and up to

45% of body protein (Sykes and Field, 1972) while successfully completing pregnancy. Similar results have been reported with hill ewes at pasture (Field et al.,1968; Sykes et al.,1974). Fat forms a large proportion of body weight loss owing to relatively lower losses of body protein and concurrent increase in hydration of tissues.

Ewes, with an initial body fat concentration of 27%, and which were fed to theoretical energy requirement (15.6 MJ ME/ewe/d) indoors during pregnancy (Heaney and Lodge, 1975), showed little change in maternal body fat or protein content from levels in early pregnancy. In a study with non-pregnant and pregnant lambs and mature ewes, Rattray et al (1974b) found that pregnancy had a similar effect to lowering the level of nutrition. Pregnant animals had decreased fat and increased water concentrations in the maternal body compared with non-pregnant contemporaries.

The influence of nutrition during pregnancy, and number of foetuses carried, on changes in maternal body composition, was studied by Robinson et al (1978). Ewes carrying 1, 2, 3 or 4 foetuses, were penned and offered feed at two basal energy allowances (13.4 and 9.6 MJ ME/ewe/d) plus an additional 1.3 MJ ME/d for each foetus carried. Maternal body weight showed increasing losses (4-8%) during pregnancy with increasing numbers of foetuses, especially on the low energy intake. Eighteen percent of body fat was mobilized during the final 8 weeks of pregnancy in ewes with 2 foetuses. Changes in total maternal body protein during pregnancy were small but re-distribution occurred with large increases in the protein content of the udder. Increases in udder size

during late pregnancy were exponentially related to numbers of foetuses carried. Ewes carrying quadruplets and on the low energy diet transferred .1.1 kg (25%) of maternal body protein to the udder. Ewes with twin foetuses maintained protein content of the carcass. Lodge and Heaney (1973) found during pregnancy a 135% increase in weight of fat and a six-fold increase in weight of protein in the udder.

Despite a lack of change in maternal body protein during pregnancy, Robinson et al (1978) found a progressive increase in the ratio of water:protein (from 3.6 to 4.3). This was attributed to increases in extracellular fluid which is often associated with undernourishment during pregnancy (Russel et al., 1968; Field et al., 1968; Sykes and Field, 1972). Although water:protein ratios are often considered constant in ruminants , Reid et al (1963) and Orskov et al (1976) showed changes in growing sheep and Cowan et al (1979,1980a) found increases in the ewe during lactation.

3.3 Changes in body composition during lactation.

The limited data available on body composition of the ewe during lactation are restricted to indoor studies. These show that losses of body fat and hydration of tissues normally occur during early lactation.

Foot and Russel (1979) suggested that sheep, typical of those grazing hill pastures, have relatively low body fat after lambing (around 3 kg) and commonly mobilize up to 50 g/d during the first 5-6 weeks of lactation. Sheep with greater initial body fat content of 9.2 kg (Cowan et al., 1979) and 19.6 kg (Cowan et

al.,1980a) and rearing twin lambs, showed higher fat losses during early lactation of 240 and 280 g/d respectively. Body protein showed maximum loss of 26 g/d in the latter experiment in ewes offered a low protein (121 g CP/kg DM) diet. Cowan et al (1980a) concluded that body fat loss was greatest in sheep with high fat reserves after lambing and a relatively low intake of a predominantly roughage diet during lactation.

The energy content of body weight loss during early lactation can vary considerably. In the study of Cowan et al (1980a), with heavy ewes (77 kg) rearing twins and offered diets with low (121 g/kg DM) or high (131 g/kg DM) CP content, body weight losses were 153 and 97 g/d, respectively, and energy losses 90 and 60 MJ/kg body weight change. Ewes with a lower initial body weight (71 kg) showed corresponding weight losses of 113 and 17 g/d and energy changes of 50 and 24 MJ/kg. Cowan et al (1979) showed the energy content of body weight loss was 68 MJ/kg in early lactation and 17 MJ/kg during late lactation (days 42-111).

It appears that body hydration, which accompanies fat mobilization, may mask change in body weight (Cowan et al., 1979,1980a; Foot and Russel, 1979). In addition, increased weight and contents of the alimentary tract during early lactation (Campbell and Fell, 1970; Fell et al.,1972; Cowan et al.,1980a) may contribute. Large variations in the energy content of live body weight loss during lactation clearly preclude use of body weight as a reliable index of energy status of the ewe.

4. FEED INTAKE IN THE EWE - A REVIEW.

4.1 Expression of feed intake

Feed intake has been expressed as DM, OM, digestible nutrients (DDM and DOM) or as metabolizable energy (ME), over 24 h periods per unit of body weight (W) or $W^{.75}$. Use of OM is preferable to DM for indirect estimates of MEI since variation in ash content is excluded.

In the following sections intake is expressed as g DOM/kg $W^{.75}$/d and MJ ME/kg $W^{.75}$/d, calculated on the basis of a theoretical energy content of 15.6 MJ ME/kg DOM (Roy et al., 1977), for uniformity. Metabolic body weight ($W^{.75}$) was recommended by ARC (1980) because of its closer relationship with intake, over a range of feeds and animal body weights, than actual weight.

4.2 Regulation of intake.

Regulation of feed intake in ruminants is highly complex and integrated. Baile and Forbes (1974) identified factors including sensory cues (sight, smell, taste and feel) in the selection of feed; regulation of energy balance by hormones and changes in fat depots; control of meal size or frequency by receptors in the alimentary tract; and integration of information in the hypothalamus. In a modelling approach Forbes (1977) suggested that capacity of the alimentary tract dominates with roughages of low energy density and that

metabolic-hormonal control is more important with diets of high energy density. A more detailed discussion of regulation of meal size and energy balance is supplied by Forbes (1979).

In the free grazing situation where diets sometimes have a relatively low concentration of DE, physical capacity of the digestive tract probably limits intake (Forbes, 1970; Dinius and Baumgardt, 1970; Hodgson, 1977). Hodgson (1977) suggested that intake is seldom, if ever, controlled metabolically at pasture. Nutritive quality of herbage is thus important for maximum feed intake.

4.3 Grazing conditions.

4.3.1 Sward characteristics and grazing behaviour.
Feed intake of grazing sheep is determined by the product of bite size, rate of biting, and daily grazing time. Interrelationships vary according to characteristics of the sward including plant height, density and mass per unit area.

Increased herbage mass has been positively related with intake (Arnold and Dudzinski, 1967; Arnold, 1975; Rattray and Jagusch, 1978; Milne et al., 1981). Arnold and Dudzinski (1967) proposed a curvilinear asymptotic relationship, passing through the origin, between herbage mass and intake. The relationship indicates that intake of grazing ewes declines rapidly when herbage mass falls below 500 kg DM/ha. This may be manifested both behaviourly by reduced rate of eating due to physical difficulty of feed prehension and by reductions in feed quality (Hodgson, 1977). Reduced intake has also been

observed at herbage masses of 560 kg DM/ha (Arnold (1975) and 1000 kg DM/ha (Rattray and Jagusch, 1978).

In a study by Arnold (1964) grazing times of sheep varied from 6-10.6 h/d and were inversely related to herbage mass, sward density, and length and were greater in lactating than dry or pregnant ewes. Arnold (1975), on the other hand, showed grazing times varied little from 9 h/d but rate of intake was reduced with decreasing herbage mass. Variation in feed intake attributable to physiological state, and breed, was largely due to differences in rate of intake. Milne et al (1981) found significant negative relationships between herbage mass and grazing time or biting rate of lactating ewes but positive relationships with bite size. At herbage masses of 500, 750 and 1500 kg OM/ha daily grazing times were, respectively 9.7, 9.1 and 7.3 h, biting rates 49, 45 and 32 thousand bites per day and bite sizes 47, 50 and 58 mg OM per bite. Mean OM intakes at the three herbage masses during the same period were 1.93, 2.49 and 2.17 kg/ewe/d respectively; the comparatively low value for the highest herbage mass was associated with an abnormally low D value.

As herbage allowance increased from 26 to 116 g OM/kg W/d, at comparatively high herbage mass (4,200 to 9,000 kg OM/ha), Gibb and Treacher (1978) found DM intake of ewes to increase linearly. Comparisons of differences in herbage allowance by varying stocking rates between 9.4 and 35.4 ewes/ha (Langlands, 1977) showed intake during lactation was not sensitive to increased stocking rate. Gibb and Treacher (1980), on the other hand found that ewes had greater intakes at a low (75 ewes/ha) compared with a high stocking density (150 ewes/ha).

4.3.2 <u>Diet selection.</u> Considerable evidence for selective grazing has been obtained in studies with O/F sheep (Arnold, 1964; Hamilton <u>et al.</u>, 1973; Donnelly <u>et al.</u>, 1974; Langlands, 1975; Penning and Gibb, 1979). Digestibility values of extrusa samples have been up to .15 greater than sward samples on poor quality pastures (D of .55) but only .02 greater on better quality pastures (D of .76). No difference was found by Milne <u>et al</u> (1981) on high quality spring pastures with OMD values above .80. In providing opportunity for selection, heterogeneous swards may reduce bite size, so unless there is compensation by increased biting rate or time spent grazing, intake may be reduced (Hughes <u>et al.</u>,1980).

4.4 <u>Digestion and rate of passage.</u>

Level of intake is often associated with D. Under pen feeding conditions, Blaxter (1962) showed DE intakes of 6.3 and 29.3 MJ/d by 40 kg sheep offered, <u>ad libitum</u>, diets of D value .40 and .85, respectively.

Physical regulation of intake is largely dependant upon the rate of disappearance of digesta from the reticulo-rumen. This is governed by rate of digestion and absorbtion of nutrients and by rate of passage of undigested material through the reticulo-omasal orifice (Balch and Campling, 1962; Ulyatt <u>et al.</u>, 1976; Baldwin <u>et al.</u>, 1977). These are influenced by chemical and physical composition of plant material ingested, microbial activity, and rate of breakdown of particle size. Interrelationships determine retention time of digesta in the reticulo-rumen, but further discussion of these is beyond the scope of this review. In summary, rate of

passage is high with leguminous diets and temperate grasses in vegetative growth.

4.5 Overriding influences on feed intake.

In addition to animal and plant factors discussed above, health status and environmental influences may have an overriding influence on intake. These include internal parasites (Leyva et al., 1981), teeth condition (Coop and Abrahamson, 1973; Sykes et al., 1974) climatic influences (Joyce and Blaxter, 1964), effects of shearing (Wodzicka-Tomaszewska, 1963,1964; Coop and Drew, 1963) and mineral or other nutrient deficiencies too numerous to consider in detail here.

4.6 Physiological state of the ewe.

The ability of the grazing ewe to meet feed requirements during pregnancy and lactation depends not only on factors discussed above, but importantly, on physiological changes in the ewe.

4.6.1 Pregnancy. Feed intake during late pregnancy is limited by increasing volume of the uterus and, sometimes, weight of abdominal fat. Forbes (1968b, 1969a) showed rumen contents may be reduced from 9 1 at week 14 of pregnancy to 5 1 at week 20. The effect on intake, however, was partly offset by a slightly greater rate of passage of digesta during late pregnancy. The effect of weight of abdominal fat in reducing rumen volume was reported by Gordon and Tribe (1951), Blaxter (1957), Crabtree (1967) and Everitt (1966). The latter showed that thin ewes consumed 3.4% of their body weight as DM in late pregnancy compared with 1.5% in fat ewes. The

additive effects of pregnancy and fatness in depressing rumen volume and intake were discussed by Forbes (1968b,1969a).

There is, in addition, some evidence for metabolic or hormonal control, with reduced intake in ewes offered high energy density feeds during late pregnancy (Forbes, 1968c). He suggested increased secretion of oestrogen may have contributed.

4.6.2 Early lactation. Ewes often fail to meet increased energy requirements during early lactation which results in loss of body energy reserves. Intake generally reaches a peak between 4-9 weeks after parturition, lagging 2-3 weeks behind peak milk production (Hadjipieris et al., 1966). Recent work with lactating ewes at pasture, however, has suggested that maximum feed intake can be achieved during the first 3 weeks of lactation (Gibb and Treacher, 1978; Maxwell et al., 1979).

There is evidence that rumen capacity may increase following parturition (Ulyatt and Barton, 1964). The alimentary tracts of housed ewes offered a high-energy diet were found to hypertrophy during early lactation (Fell et al., 1972). The small intestine showed the greatest increase and reached maximum weight 30 days after parturition while the rumen and abomasum attained maximum weight 50 days after parturition. In grazing ewes the extent of hypertrophy was found by the same authors to be less. These data suggest that the lag of feed intake behind requirement may be partly caused by the time required for adaptive changes in the alimentary tract.

High body fat content at parturition appears to suppress intake during lactation (Peart, 1970; Stern et al., 1978; Cowan et al., 1980a). This may operate through physical restriction of gut capacity (Cowan et al., 1980a) a similar conclusion as was reached with pregnant ewes (discussed above) and dry sheep (Graham, 1969). The greater intake associated with high energy demand in ewes rearing twins (Hadjipieris and Holmes, 1966; Peart, 1967), may also, in part, be attributable to leaner body condition owing to increased drain on body reserves during pregnancy compared with ewes giving birth to and rearing single lambs (Stern et al., 1978). Metabolic stimulation of intake during early lactation may be influenced by the extent of energy depletion before and after parturition (Baile and Forbes, 1974).

4.7 Estimates of voluntary intake.

Results from experiments where voluntary feed intake has been permitted, are summarised for the dry, pregnant and lactating ewe in Tables 4.1 and 4.2.

The range of values for dry ewes at pasture is 39-76 g DOM/kg $W^{.75}$/d (Arnold and Dudzinski, 1967). Higher intakes were achieved with grass cubes compared with hay (32 and 44 g DOM/kg $W^{.75}$d respectively) in an indoor study by Hadjipieris and Holmes (1966).

During pregnancy intakes of conserved forages have ranged from 22-47 g DOM/kg $W^{.75}$/d for chaffed hay and higher quality dried grass respectively (Foot and Russel, 1979). Maximum intake of 80 g DOM/kg $W^{.75}$/d was obtained at pasture (Arnold and Dudzinski, 1967).

Table 4.1 Estimates of voluntary intake of DOM and ME for dry and pregnant ewes indoors and at pasture

Authors	Ewe breed	Type of diet	Ewe body weight(kg)		Intake/kgW$^{.75}$/d DOM(g)	ME(MJ)
NON-PREGNANT						
Hadjipieris and Holmes (1966)	Border Leicester	Grass cubes	72		44	.690
	X Cheviot	Grass cubes+hay	75		38	.589
		Hay	75		32	.496
Arnold and Dudzinski (1967)	Border Leicester					
	X Merino	Pasture	46		76	1.178
	Corriedale	Pasture	50		39	.605
Gibb and Treacher (1978)	Scottish Halfbred	Pasture	81		52	.861
Maxwell et al (1979)	Greyface	Pasture	66		62	.975
Doney et al (1981)	Scottish Blackface	Pasture	69		50	.778

Authors	Ewe breed	Type of diet	(weeks from lambing)	(single,S or twin,T bearing)	DOM(g)	ME(MJ)
PREGNANT						
Hadjipieris and Holmes (1966)	Border Leicester					
	X Cheviot	Grass cubes (-6 to	82	T	45	.695
		lambing)	82	S	42	.662
		Grass cubes				
		and hay	81	T	45	.695
		Hay	90	T	41	.664
			74	S	46	.713
Arnold and Dudzinski (1967)	Border Leicester					
	X Merino	Pasture (-12 to-3)	47		80	1.241
	Corriedale	Pasture (-6 to -3)	49		45	.692
Foot and Russel (1979)	Scottish Blackface	Chaffed hay(-14 to lambing)	61	T	22	.349
		" "	62	S	23	.359
		Dried grass " "	65	T	45	.696
		" "	62	S	47	.735
Cowan et al (1980a)	Finnish Landrace X Dorset Horn	Pelleted (-14 to lambing) complete diet	82	T	50	.779

Table 4.2 Estimates of voluntary intake of DOM and ME, and milk production, for lactating ewes indoors and at pasture

Authors	Ewe breed	Type of diet	Period of lact- ation (weeks)	Twin(T) or Single(S) suckled	Ewe body weight (kg)	Intake/kg $W^{.75}$/d DOM(g)	ME(MJ)	Milk yield (kg/d)
Coop and Drew (1963)	Romney	Pasture	2-12	T	59	96	1.499	1.6
				S	60	99	1.550	1.8
	Border Leicester X Romney			T	58	89	1.393	1.8
				S	63	75	1.175	1.6
Hadjipieris and Holmes (1966)	Border Leicester X Cheviot	Grass cubes	birth-10	T	71	76	1.181	2.8
				S	75	60	.936	1.8
		Grass cubes+hay		T	68	63	.982	2.1
		Hay		TandS	63	37	.580	1.2
Peart (1967)	Blackface	Pelleted grass -concentrate	birth-10	T	61	95	1.478	2.0
				S	57	91	1.415	1.4
Arnold and Dudzinski (1967)	Border Leicester X Merino	Pasture	mean of +3 and +10	S	44	119	1.844	
	Corriedale		+3,+6 and +10	S	48	51	.795	
Treacher (1970)	Scottish Halfbred	Pelleted grass	birth-6	M	80	65	1.017	1.4
Gibb and Treacher (1978)	Scottish Halfbred	Pasture	birth-12	T	72	73	1.142	1.5
Foot and Russel (1979)	Scottish Blackface	Dried grass	birth-11					
		-dried grass preg.		T	68	82	1.286	
				S	69	71	1.121	
		-hay preg.		T	56	100	1.554	
				S	61	89	1.394	
Maxwell et al (1979)	Greyface	Pasture	birth-14	T	61	90	1.408	1.6
				S	61	85	1.325	1.3
Gibb and Treacher (1980)	Scottish Halfbred	Pasture	birth-16	T	81	54	.843	1.9
Doney et al (1981)	Scottish Blackface	Pasture	birth-8	T	63	68	1.052	2.2
				S	65	64	.988	1.7

During lactation voluntary intake of conserved forage-based diets has ranged from 37-100 g DOM/kg $W^{\cdot 75}$/d (Hadjipieris and Holmes, 1966; Foot and Russel, 1979). At pasture, values have varied from 54-119 g DOM/kg $W^{\cdot 75}$/d (Gibb and Treacher, 1980; Arnold and Dudzinski, 1967). Factors influencing intake have included type of diet and level of feeding during pregnancy (Peart, 1967; Foot and Russel, 1979), physical form of the diet (Hadjipieris and Holmes, 1966), proportion of roughage in the diet (Cowan et al.,1980a) and herbage mass (Arnold and Dudzinski, 1967; Gibb and Treacher, 1980).

4.8 Influence of nutrition on milk production and composition.

4.8.1 Nutrition during pregnancy. Effects of nutrition during pregnancy on milk production occur indirectly through body compositional changes and foetal growth. Severe undernutrition can reduce milk production by restricting mammary growth and development (Wallace, 1948; Thomson and Thomson, 1953; Rattray et al., 1974c), reducing lamb birth weight and therefore milk withdrawal ability (Peart, 1967) or by depletion of essential body reserves (Braithwaite et al.,1969; Peart, 1970). Peart (1970) suggested a reduction in ewe body weight at parturition of around 15 kg is required for significant suppression of milk production.

Variation in level of feeding during pregnancy has generally had little influence on milk yield in ewes well fed during lactation(Peart, 1967,1970; Stern et al., 1978; Maxwell et al., 1979; Cowan et al ., 1980a) but Treacher (1970) showed a response with machine milked ewes

at low levels of feed intake and milk production (0.6-1.4 kg/d). A similar effect of pregnancy nutrition has been found with dairy cows (Hutton and Parker, 1963). Stern et al (1978) showed that liberal feeding of dairy ewes during late pregnancy and heavy body condition post-partum was associated with suppression of feed intake and reduced milk yield during early lactation.

Increased feeding during pregnancy has increased fat and decreased protein concentrations in milk during early lactation in both ewes (Treacher, 1970) and dairy cows (Davenport and Rakes, 1969; Lodge et al., 1975). These effects are possibly caused by increased body fatness at parturition and a greater supply of fatty-acid precursors for milk fat synthesis (Armstrong, 1968).

4.8.2 Nutrition during lactation. Restricted nutrition during the first 3-4 weeks of lactation has reduced milk production during the period of restriction (Peart, 1970; Jagusch et al., 1972) but the effect has been less marked in fat compared with lean ewes and in those rearing twin lambs (Coop et al.,1972). Milk yield can be restored to expected levels with removal of restriction before the ewes would normally have reached peak production (Peart 1970; Jagusch et al., 1972). Responses of milk yield to increased nutrition have been greatest in ewes underfed during pregnancy (Barnicoat et al., 1949; Gardner and Hogue, 1964; Treacher, 1971). The suggestion that lean ewes are more efficient converters of food to milk than fat ewes (Peart, 1967, 1968, 1970; Stern et al., 1978) has not been substantiated by measurements of body composition.

Suppression of feed intake and milk production by body fatness appear to be partly dependant upon the quality of diet offered. Studies with sheep (Forbes 1977; Cowan et al., 1980a) and dairy cows (Bines et al., 1969) have shown a greater effect on roughage compared with higher quality diets. Cowan et al (1980a) derived a relationship showing that increased D and decreased retention time of feed in the reticulo-rumen lessened the suppression of intake caused by body fatness.

Utilization of body fat reserves for milk production has been increased with dietary supplementation of protein (Robinson et al.,1979; Cowan et al.,1981; Gonzalez et al.,1982), particularly at low energy intakes during lactation. Low levels of feeding in early lactation have been associated with increased body fat mobilization (Cowan et al.,1980a) and higher milk fat concentration as discussed above.

5. MEASUREMENT OF FEED INTAKE IN GRAZING SHEEP - A REVIEW

5.1 Summary of techniques.

Two fundamental approaches can be defined and are based on animal and sward-sampling techniques.

5.1.1 Animal techniques: The most common technique involves determination of herbage DM digestibility (DMD, expressed as a fraction) and faecal output (FO, kg/d). Intake of DM by individual animals (DMI, kg/d) is estimated from-

$$DMI = FO(DM) \times 1/1-DMD$$

Methods of measuring digestibility (D) and FO are summarised in Figure 5.1 (p.29).

Other indirect animal techniques include relationships between water turnover or water consumption and DMI (Benjamin et al., 1977) and between rumen volatile fatty acid production and energy intake (Corbett, 1978). The former relies on a constant water:DM ratio in the diet and the latter requires animal surgery and expensive infusion and sampling equipment.

5.1.2 Sward-sampling technique: Mean intake for groups of animals can be estimated from the difference between pre- and post-grazing weight of herbage determined from mechanically harvested sward samples. Estimates are based on the following expression -

$$DMI \ (kg/d) = \frac{\text{pre-grazing DM (kg)} - \text{post-grazing DM (kg)}}{\text{number of sheep grazing days}}$$

Adjustments for pasture growth over the measurement period, if significant, are required.

5.2 Animal techniques.

5.2.1 Direct measurement of faecal output. Direct measurement involves the total collection of faeces in bags attached to the animal (Sears and Goodall, 1942; Cook et al., 1952; Royal, 1968). Normal grazing behaviour and performance may be affected either by the burden of the collection equipment or by chafing which sometimes occurs. The inability to detect faecal losses with loose or badly fitting bags is a potential source of error and urine contamination in the case of female sheep can cause problems. Mesh-bottomed bags which allow the passage of moisture can be used with female sheep or urine contamination can be prevented by use of bladder catheters to by-pass the bag. Raymond et al (1953) and Ingleton (1971) have used harnessed and bagged sheep for long periods with apparently few problems. Corbett (1960) concluded that total faecal collection is expensive, time consuming and impractical in some situations.

5.2.2 Estimation of faecal output. Indirect measurement has most commonly involved the use of chromium sesquioxide (Cr_2O_3). This indigestible marker is administered orally incorporated in gelatin capsules or paper (Corbett et al., 1960). Daily FO (g) is obtained as follows –

$$FO = \frac{1000X}{Y}$$

where - X = Cr_2O_3 administered (g/d)

Y = Cr_2O_3 in faeces (mg/g DM)

Problems with the method include incomplete recovery of Cr_2O_3 (Kotb and Luckey, 1972) due to regurgitation, losses during milling of samples, variation in prescribed doses or an insufficient preliminary dosing period (about 5 d is required) for the marker to reach equilibrium in digesta.

Erratic diurnal patterns of concentration of Cr_2O_3 in faeces have been observed and attributed to incomplete mixing of the marker with digesta (Lambourne and Reardon, 1963; Langlands et al., 1963a). These workers found, that twice daily dosing and faecal sampling, at intervals of approximately 8 and 16 h, gave best results but errors in Cr_2O_3 recovery of +2% to -9% were still found. Bias due to systematic errors was overcome by use of correction factors based on differences in Cr_2O_3 concentration between samples from total faecal collections and grab-samples taken from the same animals. Differences of +5% to -15% between FO estimates from total collections and grab-samples have been obtained (Langlands et al., 1963a).

Chromic oxide mixes in the liquid phase of digesta and this may contribute to variation in its concentration in faecal DM (Raymond and Minson, 1955). Rare earth elements which attach to undigested fibre residues may offer advantages by showing less variation in concentration in faeces. Radiocerium oxide (Huston and Ellis, 1968) and Dysprosium (Ellis, 1968) have been used;

```
                                    direct - total collection

                    faecal output

                                    indirect - external marker

                                              (Cr₂O₃)

        INTAKE

                                    direct - digestibility trial

                    digestibility

                                    indirect - in-vitro
                                                determination

                                          -   internal marker
                                              (feed/faeces)
```
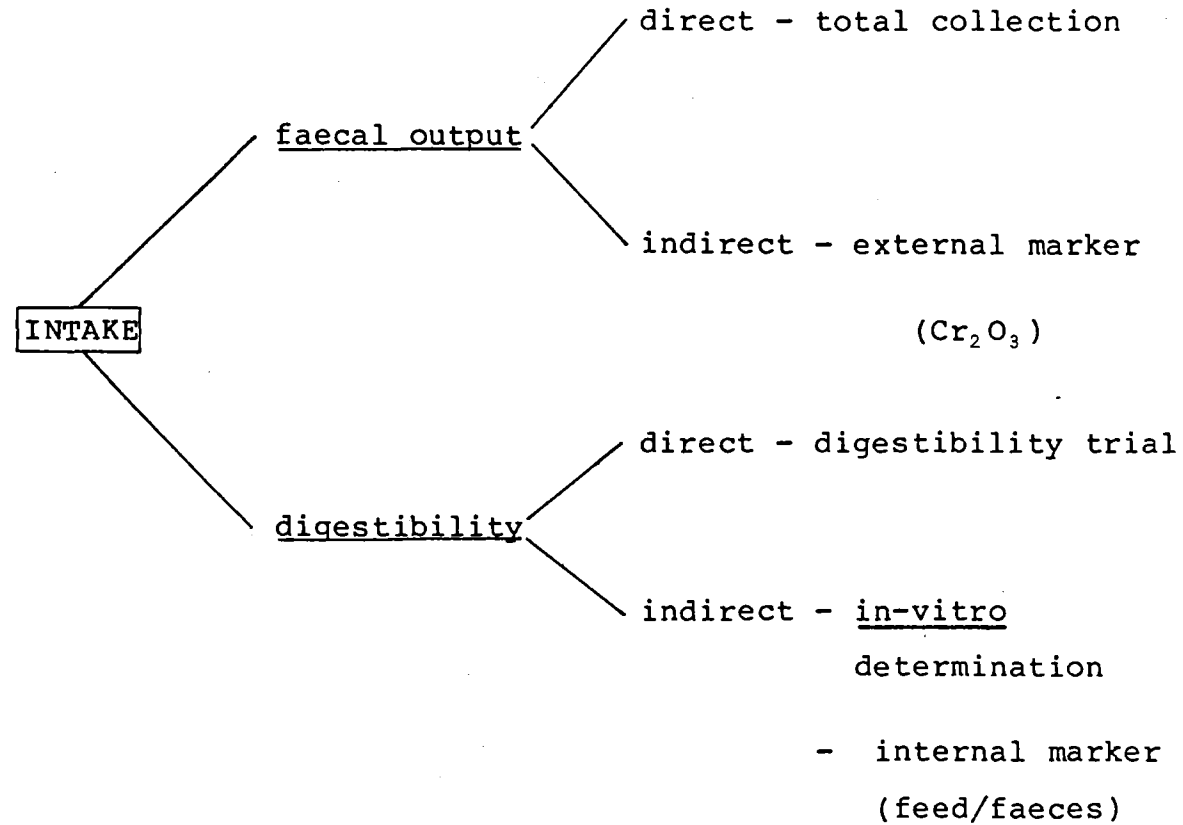
Figure 5.1 A summary of methods for measurement of faecal

output and digestibility for estimates of

feed intake.

specialised equipment is required for measurement, however (eg. neutron activation for the latter).

Faeces have been sampled for Cr_2O_3 by collecting samples from the sward (Raymond and Minson, 1955; Langlands et al., 1963b) with individual animals identified by dosing with different coloured polystyrene particles (Minson et al., 1960). The method is practical only with small numbers of animals and is laborious and time consuming.

Faecal output has been predicted from water turnover using tritium dilution (Macfarlane et al.,1969). The method has the advantage that animals can be left to graze undisturbed over the measurement period of 4-5 d. Drinking water must, however, be witheld and success of the method can be affected by rainfall or dew. Correlation coefficients between water turnover and FO of .93 (Macfarlane et al., 1969) .86 (Macfarlane et al., 1972) and .80 (Geenty, 1975) have been reported. The relationship may be more variable under temperate compared with sub-tropical conditions, possibly due to greater fluctuations in water:DM ratio in herbage.

5.2.3 Animal measurement of digestibility. Direct in-vivo measurement of D of grazed herbage is difficult due to the problem of harvesting material actually selected by grazing animals. Careful observation of selection by grazing animals and hand plucking of equivalent material has been attempted (Cook, 1964; Langlands, 1974). The method is time consuming and the sample still only approximates the actual composition of herbage selected (Langlands, 1974).

Digestibility has been estimated indirectly using a faecal index method (Raymond et al., 1954). This is based on relative concentrations of an indigestible component in the feed (X) and faeces (Y) where -

$$D = \frac{(Y-X)}{Y}$$

Reference substances have included plant constituents of lignin, silica and some chromogens but none have shown complete resistance to digestion and ease of analytical determination (Kotb and Luckey, 1972).

As a consequence faecal indicators, most commonly chromogens and N, have been used in preference to determine D. The latter is more easily determined and a more precise indicator of D (Kennedy et al., 1959; Greenhalgh and Corbett, 1960).

Most N in faeces is of endogenous origin and includes debris from the alimentary mucosa and microbial population; approximately 5-10% is of dietary origin. As the D value of herbage and DMI increase, FO per unit of feed intake becomes proportionately smaller and so N concentration in faeces increases. Values of D for food consumed by grazing sheep can be derived from regressions of D on faecal N obtained in concurrent in vivo digestibility trials (Raymond, 1948; Lancaster, 1949). Relationships between D and faecal N will vary according to parasite burden, plant species, season, N fertiliser application and level of intake, so estimates must be based on "local" regressions with conditions standardised (Raymond et al., 1956; Greenhalgh et al., 1960,1966). The problem of obtaining a representative sample of

herbage for _in vivo_ estimate of D still remains. Langlands (1967b) found a lower regression coefficient in data from oesophageal extrusa compared with harvested grass. Ingestion of faeces or soil can result in overestimates of intake by this method (Lambourne and Reardon, 1963; Young and Corbett, 1972).

5.2.4 Laboratory measurement of nutritive value.

Laboratory methods to determine nutritive value of forages have been based on partitioning into chemical, and more recently, structural components. One of the most widely used methods is the detergent extraction system (Van Soest, 1963). Neutral detergent is used initially to remove cell contents, leaving partially digestible neutral detergent fibre. This is further partitioned, using acid detergent, into an acid soluble fraction (fibre-bound protein and hemi-celluloses) and acid detergent fibre (cellulose, lignin, and lignified N compounds). Lignin can be determined from the fibre fraction by oxidation with $KMnO_4$ and cellulose obtained by difference. Most plant silica, however, which is non-nutritional, is extracted in the neutral detergent solution, so this fraction is not always a true indication of cell contents (Keys et al., 1969).

Even when plant components can be accurately partitioned by chemical methods, biological _in vitro_ techniques are preferable for measurement of D (Oh, et al. 1966) due to effects on nutritive value of variation in physical distribution and organisation of these components within the plant.

As a consequence in vitro techniques have been developed. These simulate in vivo digestion by controlled anaerobic incubation of a small test sample of the feed in a nourished and buffered rumen liquor medium at body temperature. A two stage system, including a second acid-pepsin digestion stage to simulate enzymatic digestion in the abomasum, was developed by Tilley and Terry (1963). Van Soest, Wine and Moore (1966) replaced acid-pepsin by neutral detergent digestion. These methods have been used extensively in nutritional studies.

A recent development has been the replacement of rumen liquor as a source of the cellulase enzyme, by cell-free extracts of fungal cellulase in a single stage digestion in combination with pepsin (Jones and Hayward, 1975; McQueen and Van Soest, 1975). Results have compared well in accuracy with the method of Tilley and Terry (1963).

Even though in vivo D values can be predicted from the use of well proven in vitro techniques outlined above, a possible source of bias is level of feeding which is difficult to account for with the latter method. Robertson and Van Soest (1975) have shown depressions in OMD coefficients, with increased intake from 1X maintenance to 2X maintenance, of .051 and .028, respectively, on diets with high and low fibre content. With a 50:50 conserved forage:concentrate diet, Gardner and Hogue (1966) observed a reduction in TDN coefficient of 0.05 with each increased maintenance increment of feeding in the lactating ewe. Increased D with increasing intake was reported by Webster et al (1974) for a concentrate diet offered to sheep and cattle. There is a lack of information on level of feeding effects on D in

the lactating ewe with fresh herbage diets, though Hutton (1963) showed only a small effect (.001 DE) in the lactating dairy cow.

5.3 Herbage selection - the oesophageal fistula technique.

Torrell (1954) first used animals fistulated at the oesophagus to measure herbage selection. Surgery is simple (McManus et al., 1962) and if animals are given access to "soft" feed such as green pasture, healing is rapid and extrusa sampling can begin within 6-8 weeks. Non-removeable rigid cannulas with a screw cap have been used for sampling but a moulded rubber plug, in the form of two "L" pieces held in place externally by a strong rubber ring, has been found more satisfactory (Corbett, 1978). Leakage of saliva may cause Na depletion but this can be remedied by provision of salt licks.

Extrusa is sampled into a plastic bag secured around the orifice (Corbett, 1978) and collections made over periods of up to 0.5 h. If the fistula is small or badly positioned, large pieces of the feed may be swallowed causing the sample to be unrepresentative of material eaten. Short periods of fasting prior to collection may prevent extended collection periods and the risk of regurgitation of rumen contents. Fasting up to 12 h has little effect on D of extrusa samples (Sidahmed et al., 1977).

Non-enzymic browning of extrusa with consequent reduction of D value may occur if saliva is not rapidly removed (Langlands, 1966). Since its removal by squeezing also removes some OM of feed origin, Langlands (1975) has derived an equation, from results with temperate forages,

for estimating D percentage of feed consumed (Di) from D percentage of the extrusa sample following removal of saliva (Ds), where -

$$Di = 38.5 + 0.00695(Ds)^2 \quad RSD = 2.5$$

Although variation in the composition of diets selected on the same pasture occurs within and between animals (Arnold et al., 1964; Langlands, 1967a,1967b,1969a), Langlands (1969b) concluded that the O/F technique provides better estimates of D than does faecal N.

5.3.1 Chemical and botanical composition of herbage selected. The N content of extrusa herbage has been the same as in fresh herbage (Langlands, 1966) as have been plant structural carbohydrates (Torrell et al., 1967; Hoehne et al., 1967). Success of measuring minerals in extrusa varies; Ca has been estimated accurately (Hoehne et al., 1967; Langlands, 1966) but Na, P and Cl levels are increased by salivery contamination and K is reduced by leaching (Langlands and Bowles, 1973).

Estimates of the botanical composition of extrusa using a binocular dissecting "hit" method have been reported (Heady and Torrell, 1959) but Hall and Hamilton (1975) suggested results may be biased owing to weight differentials of "hits". Wagner (1952) emphasised the need to base estimates of botanical composition on weights of components. Hodge and Doyle (1967) described a method for separating botanical components of extrusa obtained from lambs using a flotation method.

Other methods of estimating botanical composition of herbage consumed have been examination of rumen contents (Van Dyne and Torrell, 1964) and identification of cuticularised plant epidermis (Croker, 1959; Hercus, 1960; Storr, 1961) but some bias may arise due to partial digestion (Slater and Jones, 1971).

5.4 Estimates of errors.

5.4.1 Animal techniques. Errors in the final determination of intake by animal methods derive from errors in the estimation of D and FO; these, coupled with animal variation, combine to give the final CV. Errors in estimating D are compounded by use of indigestibility (i.e. 1/1-D) in calculating intake, eg. a 1% error in D, when D is 0.7, results in a 3.3% error in intake. Errors of 6-12% are common in the estimation of FO using the Cr_2O_3-grab-sampling method and are often in the range of 3-5% for indigestibility derived from in vitro methods (Corbett, 1978). These errors combined give a total error of up to 16%. The range of CV's in different experiments has been 7-20% (Butterworth, 1965; Heaney et al., 1968; Ulyatt, 1972).

5.4.2 Sward sampling techniques.

The "difference" method can measure mean intake by groups of animals and is most successful over short grazing intervals (4-5 d) and when pasture growth is minimal (Walters and Evans, 1979). Sampling errors are often large but can be minimised by use of a capacitance meter (Fletcher and Robinson, 1956; Campbell et al.,1962; Jones and Haydock, 1970) or sampling strips (Walters and

Evans, 1979) in preference to quadrats (Campbell, 1969).
Final errors are the sum of those from pre- and
post-grazing samplings and CV's have ranged from 7-52%
(Green, 1949; Linehan, 1952; Green et al.,1952;
Davison, 1959; Lowe, 1959; Walters and Evans, 1979).

6. MEASUREMENT OF MILK PRODUCTION IN THE EWE - A REVIEW

Measurement in sheep used for dairy purposes is relatively simple as they are regularly hand- or machine-milked (Boyazoglu, 1963). Estimates of milk production in ewes rearing lambs, however, are more difficult owing to the production-consumption interdependance between mother and offspring and interference of measurement techniques with natural behaviour. Despite these difficulties effective techniques have been developed as follows -

(a) lamb suckling and weight differential

(b) hand- or machine-milking of the dam

(c) measurement of water turnover in the lamb

6.1 Lamb suckling and weighing.

The weight increment of the lamb during suckling, following separation from their mothers during 4-6 successive periods over 24 h, and repeated at approximately weekly intervals (Wallace, 1948), has been most extensively used. Problems include the possible depression of lamb milk intake caused by interference with normal suckling behaviour (Coombe et al., 1960; Moore, 1962), short-term appetite and intake limitations of the lamb (Wallace, 1948; Barnicoat et al., 1949; McCance, 1959), inaccuracies in lamb weight increment due to voiding of faeces or urine (Wallace, 1948; Coombe et al., 1960; Owen, 1957; Peart, 1967) and possible suppression of ewe feed intake and milk secretion due to anxiety of separation during test periods (Owen, 1957). In a review,

Doney et al (1979) concluded there will be a slight tendency to underestimate daily yield, particularly during early lactation, but final errors will be small.

6.2 Sample milking.

In an attempt to develop a better method of measurement, McCance (1959) perfected the technique, unsuccessfully tried by Barnicoat et al (1949), involving hand milking after administration of oxytocin. The method involved separation of ewes and lambs, on chosen measurement days, for a period of 2, 4 or 6 h, and hand-milking at the start and end of the period after intravenous injection of oxytocin. Daily production was obtained by extrapolation over 24 h.

McCance (1959) suggested that three criteria should be met for success of the method - (1) milk obtained over the test period must be representative and include no residual milk i.e. emptying of the udder must be similar at the initial and final milking; (2) rate of milk secretion over the test period must represent the rest of the extrapolated period; and (3) the rate of milk secretion in the short or long term must not be affected. It was concluded that although supernormal emptying probably occurred, criteria (1) and (3) were met but that secretion rate was higher over a 2 h compared with 4 or 6 h periods. Corbett (1968) modified McCances method by use of machine-milking.

Success of the direct estimation of milk production by hand- or machine- milking in ewes rearing lambs, necessitates the use of exogenous oxytocin (Linzell, 1972). It is synthesised in the hypothalamus and stored

in the posterior pituitary lobe and is released in response to suckling. This causes milk to be expelled from the alveoli into the duct system of the mammary gland by the contraction of myoepithelial cells (Cowie et al., 1951). Release of adrenalin in response to fright or emotional stress blocks secretion of oxytocin (Barowicz, 1979) and inhibits milk ejection.

The sensitivity threshold of myoepithelial cells to exogenous oxytocin may be relatively high in sheep (Labussiere et al., 1969) and dose rates need to be greater than the normal physiological range, measured in vivo, in response to lamb suckling (Thompson et al., 1973). There have been several studies on the dose required to achieve milk withdrawal (McCance, 1959; Corbett, 1968; J. N. Peart, cited by Doney et al 1979) and in general 5 IU has been found adequate. A suggestion of differences in dose-response relationships both between breeds (McCance, 1959) and individual sheep (Labussiere et al., 1969) indicates, however, that spot checks for residual milk, using repeat doses, may be warranted.

To achieve the objective of emptying the udder at the beginning and end of the test period, milking must quickly follow oxytocin injection, with minimum disturbance, owing to the evanescent nature of oxytocin (Folley, 1952; Thompson et al., 1973) and the variable reaction of sheep to being handled (Linzell, 1972).

Several workers have investigated the effects of exogenous oxytocin administration on milk secretion rate. Intermittent use in suckled or machine milked ewes or cows, separated by several days, has generally had no effect on secretion rate (McCance, 1959; Denamur and

Martinet, 1961; Morag, 1968; Thompson et al., 1973). Continuous administration in machine-milked ewes, however, has shown galactopoeitic responses. Denamur and Martinet (1961) found an increase of 15-30% in production over lactation when residual milk was removed with oxytocin injections and Morag and Fox (1966) reported a 30% increase in yield over 10 days with repeated doses of oxytocin (30-60 IU/d). A 35% fall in daily milk production was, however, reported by Morag (1969) following an extended period of oxytocin treatment. An initial response of around 40% was found by Geenty (1980) with doses of 5 IU prior to twice daily milking but this diminished to zero after 10 weeks. It was suggested the diminution in response was either due to an inhibition of the milk ejection reflex with repeated doses of oxytocin (Denamur, 1965; Carrol et al., 1968) or gradual conditioning to machine milking of ewes not treated with oxytocin. Doney et al (1979) suggested the apparently greater galactopoeitic effect of exogenous oxytocin in machine-milked ewes compared with dairy cows may be due to better adaptation of cows to machine milking without oxytocin. Treacher (1970) and Geenty (1980) have shown that machine-milked ewes, not treated with oxytocin, have much lower milk production than do those suckled by lambs.

6.3 Water turnover in lambs.

The method is based on dilution of tritiated water and estimation of body water turnover during a given period (Macfarlane et al., 1969). On the assumption that all water consumed during the measurement period (5-7 d) is derived from milk, mean daily consumption of milk by lambs can be estimated. An advantage of the method is the

minimal disturbance and interference of animals. A serious disadvantage is the overestimation of milk consumption when milk ceases to be the sole source of dietary water (Yates et al., 1971; Geenty et al., 1983). This problem can be overcome by the use of a double isotope method (Wright and Wolff, 1976) which differentiates between milk water and total water consumed by lambs. Both methods rely on the use of radio-isotopes and involve considerable laboratory committment.

6.4 Comparisons of techniques.

The choice of measurement technique depends on the objectives of individual experiments and facilities available. To interpret milk production estimates in different experiments, however, information is required on direct comparisons between techniques.

Several experiments have compared milk production estimated by oxytocin and lamb suckling. Estimates have been 6-20% greater with oxytocin compared with lamb suckling (Coombe et al .,1960; Moore, 1962). The lower production with lamb suckling was attributed to reduced capability of lambs to withdraw milk and behavioural problems with the ewe. Moore (1962) suggested the greater yield obtained by Coombe et al (1960) using oxytocin may have been due to use of a 2 h instead of a 4 h production period. Doney et al (1979) showed little difference between oxytocin or lamb suckling estimates in different breeds rearing single or twin lambs.

Relationships between ewe milk production, estimated from sample milking after oxytocin administration, and lamb water turnover (i.e. milk

intake), have suggested that oxytocin can overestimate milk production by up to 24% during early lactation (initial 2-3 weeks) in Dorset ewes rearing twins (Geenty et al.,1983). In contrast, Romney ewes rearing twins showed lower milk production than suggested by the water turnover of lambs.

There remain, then, possible problems both with use of lamb suckling or oxytocin for sample measurement of milk production. Lamb suckling may underestimate milk production due to behavioural problems or removal capacity limitations, while galactopoeitic effects or supernormal emptying,may cause overestimation with oxytocin.

7. MEASUREMENT OF BODY COMPOSITION - A REVIEW

In a review on body composition Seebeck (1968) divided studies into two categories - (a) measurements on different animals slaughtered over a pre-arranged sequence of times (cross-sectional) and (b) in vivo measurements on individual animals over a sequence of times (longitudinal). Cross-sectional studies involve use of the long established comparative slaughter technique (Moulton, 1923) which is based on the assumption that a sample of live animals of similar breed, live weight, sex and nutritional status as the animals slaughtered have the same body composition. The technique has been used extensively but has the disadvantage of being expensive and time-consuming. Longitudinal studies, on the other hand, most commonly employ radio-isotopes or heavy water to measure total body water. Body composition is estimated from body weight and prediction relationships from slaughtered animals. The technique has been used for determination of body composition in growing sheep on a constant plane of nutrition (Panaretto, 1963; Searle, 1970a, b; Smith and Sykes, 1974; Donnelly and Freer, 1974). Varying relationships with body water have been found with tritiated water between lactating and non-lactating ewes (Sykes, 1974) and between stages of lactation using deuterium oxide (Cowan et al., 1980b).

These problems in the lactating ewe have been attributed to rapid changes in body water content during early lactation owing to increasing gut fill and body hydration. The changes affect proportional distribution or equilibration of the marker leading to inaccuracies in prediction of total body water. Cowan et al (1980b) concluded that comparative slaughter measurements of body

composition in the lactating ewe are preferable.

Methods of direct measurement of body composition in animals slaughtered involve both physical and chemical fractionation of the carcass (Seebeck, 1968). In studies of body energy balance, estimation of gross chemical composition of the whole empty body and/or determination of energy content from a representative sample, are most appropriate.

8. CONCLUSIONS ON LITERATURE REVIEW

Determination of energetic efficiency in the lactating ewe at pasture requires accurate measurement of feed intake, milk production and body composition. Estimates of faecal output using chromic oxide dilution and in vitro digestibility of diets selected, appear the best techniques for measuring individual intake. Sample measurements with oxytocin to determine milk production are probably most accurate with ewes rearing twin lambs, though overestimation may occur. Lamb suckling, on the other hand, tends to underestimate milk production. The long established comparative slaughter method appears preferable to indirect in vivo methods for determination of body composition and energy content in the lactating ewe.

Feed intake in the grazing ewe is controlled by animal, plant and environmental factors. During periods of greatest feed demand, such as late pregnancy and early lactation, limitations to intake may be imposed by physical capacity of the digestive tract, particularly with low energy roughages. Hence sward characteristics and herbage qualities which favour rapid ingestion and a fast rate of passage are important for maximum intake.

Estimates of feed intake and milk production, although plentiful, are relatively scarce for the grazing ewe. There is little information on changes in body composition in the grazing ewe during pregnancy and lactation. Consequently no direct estimates are available on requirements and utilization of energy in the lactating ewe at pasture.

The two experiments described in the next chapter were designed to measure herbage intake, milk production and changes in body composition of grazing ewes, on low or high herbage allowances during pregnancy and offered low, medium or high allowances during lactation. The objective was to measure the partitioning of dietary energy between maintenance and milk production and the efficiency of use of energy, from dietary and body sources, for milk production.

9. INFLUENCE OF NUTRITION AND BODY COMPOSITION
ON MILK PRODUCTION IN THE GRAZING EWE

(Experiments A and B)

MATERIALS AND METHODS

Two experiments were conducted between May and October of 1979 (Expt.A) and 1980 (Expt.B) at the Templeton Agricultural Research Station on the Canterbury plain 17 km south-west of Christchurch.

9.1 Climate, soils and pastures.

Permanent pastures established on Waimakariri silt loam soils and with a previous history of sheep grazing were used. The dominant plant species were perennial ryegrass (Lolium perenne L.) and white clover (Trifolium repens). Animal responses to Se therapy occur in the area but soil tests indicate no other mineral deficiencies. Air temperatures and rainfall were recorded daily at 0900 h NZST under standard meteorological conditions 300 m from the experimental site.

9.2 Design of experiments.

The two experiments were designed to measure the effects of low and high herbage allowances during pregnancy, and 3 allowances during lactation (i.e. 2 X 3 factorial), on changes in body weight and composition, feed intake and energetic efficiency of milk production during the first 6 weeks of lactation in the grazing ewe.

Body weight targets are shown in Fig. 9.1 and a summary of the timing of measurements in Fig. 9.2.

In Expt.A lambs were removed following parturition and the ewes machine-milked. In Expt.B ewes were suckled by twin lambs but an additional group were machine-milked to provide continuity with Expt.A. Body composition was determined by comparative slaughter during week 6 of pregnancy, 3-10 d post-partum and at the end of week 6 of lactation.

9.3 Animals.

Mixed age (3-6 years) Dorset ewes (Poll Dorset and Dorset Horn) were used. Oestrus was synchronised using progestagen impregnated sponges (40 mg "Cronolone", G. D. Searle and Co. Ltd.) and ewes mated with Suffolk rams during early May. Six weeks later they were allocated hierarchically into weight and age groups before random allocation to treatment groups as shown in Table 9.1.

9.4 Nutritional treatments.

Herbage allowances during weeks 6-16 of pregnancy were imposed to achieve maternal body weight differences of 10-15 kg between L- and H- groups. During the final 4-5 weeks of pregnancy, allowances in each group were increased (Fig. 9.1) to avoid metabolic disorders. Allowances were adjusted on the basis of herbage available above ground level (kg DM/ewe/d) and different areas. During lactation, herbage allowances were intended to provide a range of feeding levels from moderate restriction (-L) to ad-libitum (-H) (i.e. anticipated utilization < 30%).
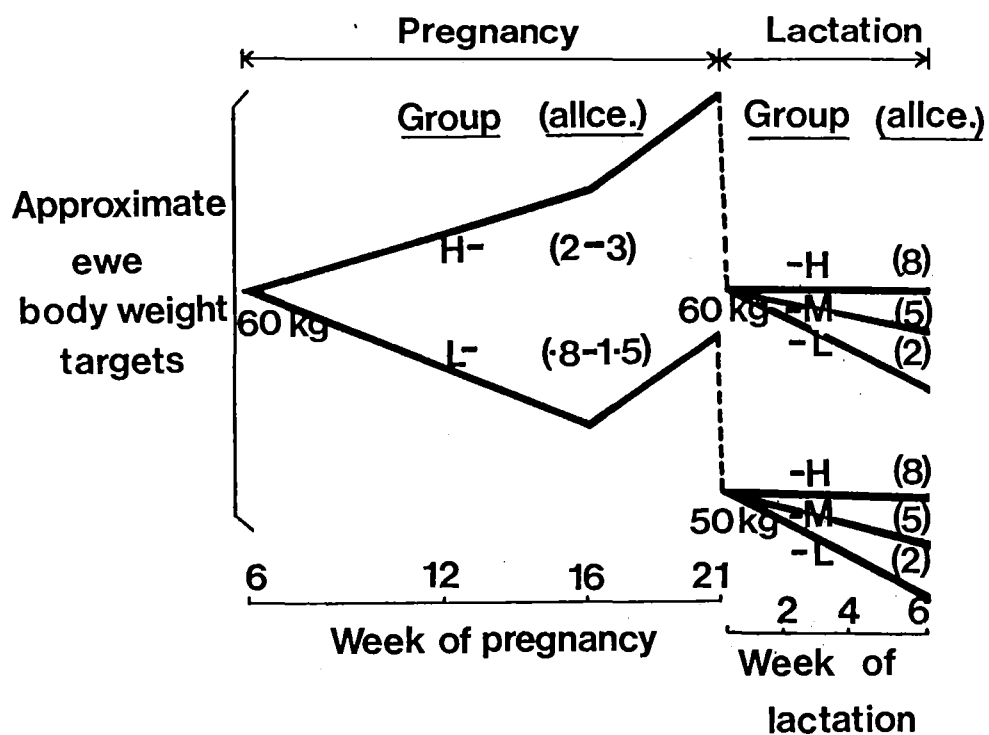
Figure 9.1: Schematic representation of ewe body weight

targets during pregnancy and lactation and

approximate herbage allowances (kg DM/ewe/d)

for groups in Expts. A and B.

Time measurements taken |←———Pregnancy———— ✳——Lactation——→|

| Comparative slaughter (Sl) for estimates of body composition | Sl | | Sl | | Sl |

Sl ... Sl ... Sl

Wool weight including greasy fleece weight (GFW) and mid-side patches (S, Expt.A)

GFW ... GFW / S ... GFW / S

Sward samples (at 3 day intervals) for herbage quality and nutritive value

←————————————————————→

Ewe body weight (weekly)

←————————————————————→

Faecal output from Cr_2O_3 dilution during 6 day periods

←——→

Extrusa samples from O/F ewes for estimates of diet selection (alternate 3 day periods)

←——→

Milk production
-daily by machines
(Expt.A)
-weekly by sample
measurements
(Expt.B)

←——→

|———————————|
6   12   21 |——————|
   Week of pregnancy   2   4   6
                        Week of lactation

Figure 9.2   A summary of the timing of measurements in Expts. A and B.

Table 9.1 Numbers of ewes in herbage allowance treatments and slaughter groups in Expts.A and B

Period	Herbage allowance +		Slaughter group	Number of Ewes in each group	
	Pregnancy	Lactation		Expt.A	Expt.B
Early pregnancy	–	–	ISG	10	10
Post-partum	L–	–	L–	11	10
	H–	–	H–	9	10
	L–	–L	LL	11(m)*	10(s)*
	H–	–L	HL	13(m)	9(s)
Lactation	L–	–M	LM	10(m)	10(s) + 11(m)
	H–	–M	HM	13(m)	10(s) + 10(m)
	L–	–H	LH	11(m)	9(s)
	H–	–H	HH	12(m)	10(s)
			TOTAL	100	109

+ L–, low; H–, high; –L, low; –M, medium, –H, high.

* m, machine-milked; s, twin-suckled.

9.5 Management.

Groups were allocated fresh pasture every 3 days using electrified flexible netting to adjust areas (Fig. 9.3). During pregnancy the L- group grazed pastures after the H- group.

Ewes were injected 3 weeks before lambing with a multi-purpose clostridial vaccine containing Se. In both experiments ewes lambed during 5 days in late September. In Expt.A lambs were removed from half of the ewes 2-5 d after parturition (group 1), and the remainder a week later (group 2), to spread the work load. Milking therefore commenced, on average, 3 and 10 days after lambing, respectively. The groups were run together and measurements combined and presented as means for weeks 1-6 of lactation. Lambs were removed from ewes, and machine-milking commenced in Expt.B (groups LMm and HMm) 2-5 d after lambing. These lambs, with those from ewes slaughtered, were fostered onto remaining ewes so all ewes with lambs reared twins.

9.6 Measurement of milk production.

9.6.1 Ewes machine-milked. Milking was done on a raised steel platform with individual headbails and feed troughs, using a commercially available plant (Alfa Laval, Sweden), with 3 sets of cups, and graduated measuring cylanders. Stainless steel cups each weighed 120 g, vacuum was 47 kPa and pulsation rate 90/min with an on:off
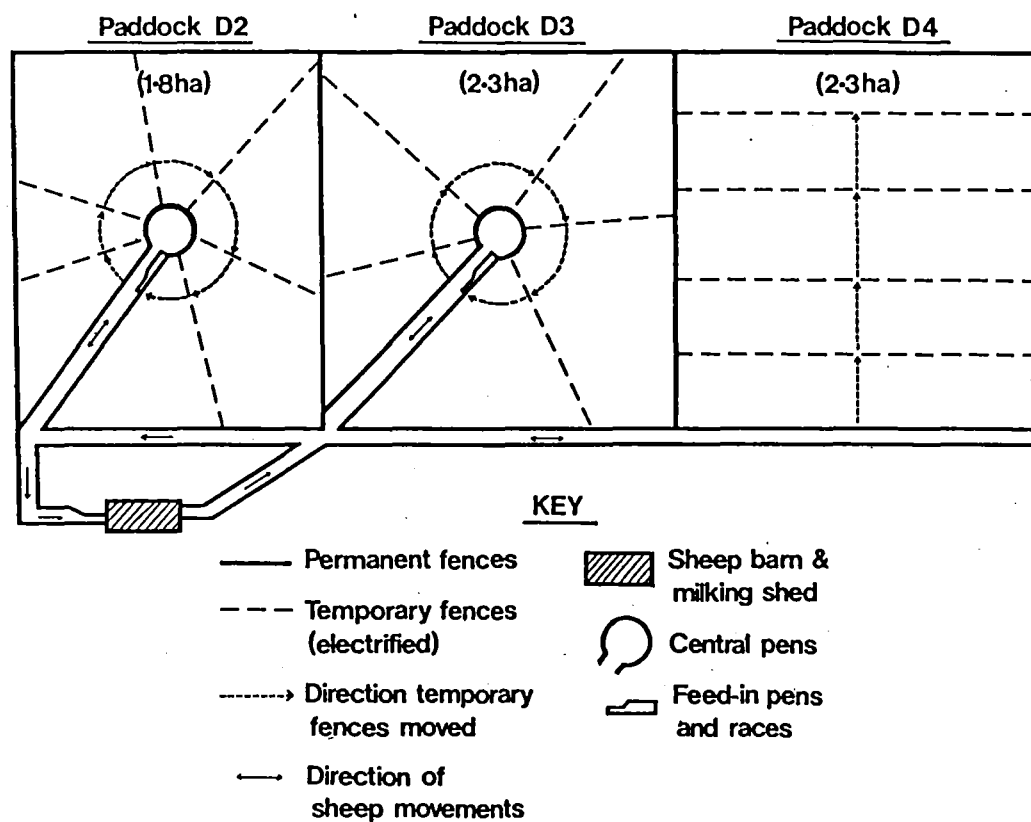
Figure 9.3: Layout of the experimental area showing facilities, pasture areas and method of sub-division used to achieve the different herbage allowances in Expts. A and B.

ratio of 50:50. To encourage ewes into the bail they were offered 50 g (Expt.A) or 35 g (Expt.B) of oaten grain during milking and the quantity consumed was assessed subjectively. The grain had an in-vitro digestibility (DMD) of .70 and GE content of 17.2 MJ/kg DM. Before milking ewes were injected intramuscularly with 10 IU oxytocin and udders stimulated (Geenty, 1982) to obtain maximum yield. Following milking udders were sprayed with a teat sanitizer and glycerine to prevent teat cracking and mastitis infection. Milking rate was about 35 ewes/h.

Individual milk production was measured volumetrically and one day each week milk from each ewe was weighed and a 100 ml sample taken for laboratory analysis.

9.6.2 Ewes rearing lambs. Measurement of milk production in ewes suckling lambs (Expt.B) was done one day each week using one of 2 combinations (Fig. 9.4) of the lamb suckling and weight differential (Wallace, 1948) and oxytocin-sample milking techniques (McCance, 1959; Corbett, 1968). The two techniques were used to avoid possible bias in measurement of milk production due to overestimation with oxytocin and underestimation with lamb suckling. Two combinations were employed for comparison.

Approximately half of the ewes in each treatment were permanently allocated at random to each combination of techniques (i.e. methods 1 and 2). Lambs were separated from their mothers in the mornings (0900-1100 h) and ewes machine-milked following oxytocin injection. After a measured interval of about 4 h ewes assigned to method 1 were suckled by their lambs (S1) and those to

56
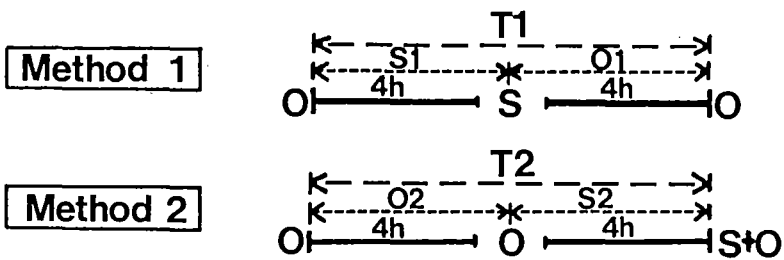
Figure 9.4:   Schematic representation of the two methods

used for measuring milk production of ewes

rearing lambs.   Techniques include

oxytocin-sample milking, O;   lamb   suckling

and weight differential, S;   and combination

of the two, T (Expt. B).

method 2 machine-milked again (O2). Following a further interval of 4 h, ewes in method 1 were machine-milked (O1) and those in method 2 suckled by lambs (S2) followed by machine milking to measure residual milk.

The same milking plant and procedure described previously was used. Daily milk production (MY, kg/d) was estimated using the following expression-

$$MY = (24/t) \ X \ W$$

where: t = time interval (h)

W = lamb weight increment or weight

of milk (kg).

Results were obtained for O and S measurements and a combination of the two methods (T) over the 8 h period.

9.7 Estimation of herbage intake.

Herbage intake was estimated in 2 ways -

(a) during lactation in individual ewes from measurements of FO during 6 day periods using Cr_2O_3 dilution and in-vitro D.

(b) during pregnancy and lactation in herbage allowance groups during 3 day grazing intervals from sward samples and DM dissappearance.

9.7.1 Measurement of faecal output. During lactation ewes were dosed twice daily (0800-1000 h and 1600-1800 h) with a capsule containing 1 g of Cr_2O_3 suspended in gelatin (R.P. Scherer Pty. Ltd., Melbourne,

Australia). Dosing commenced approximately 3 days (group 1) and 10 days (group 2) following lambing in Expt.A and 3 days after lambing in Expt.B. Individual treatment groups were dosed in the same order each time. Following an initial 6 days of dosing, grab samples of faeces were taken twice daily from the rectum at the same times; these were each standardised volumetrically at about 4 ml. To check for bias in Cr_2O_3 concentrations in grab samples (see p28), 2 ewes in each allowance group were fitted with bags for total faecal collection. Catheters were inserted into the bladder (C.R. Bard, Sunderland, England) to prevent urine entering the bags. All samples were bulked for individual ewes over the 6 days of each intake period and stored in airtight containers at -10 °C prior to estimation of Cr_2O_3 concentration.

FO was estimated during individual periods using the expression on p 28 .

9.7.2 <u>Diet</u> <u>selection.</u> Approximately 6 weeks prior to parturition 2 ewes destined for each lactation allowance group were prepared with oesophageal fistulae using the "split plug" method of McManus <u>et</u> <u>al</u>. (1962) and surgical procedures outlined by Schutte <u>et</u> <u>al</u>. (1971). During lactation O/F ewes grazed with their respective treatment groups and, during alternate 3 day periods, were used for extrusa collection. This was done following the morning milking in Expt.A and the morning grab-sampling in Expt.B. In the latter case O/F ewes and their lambs were separated from treatment groups the previous evening, for convenience, and grazed overnight on similar pastures in raceways. In both experiments plugs were removed at about 1100 h, plastic bags fitted and the ewes allowed to graze for 10-15 min with their treatment

groups. Extrusa was squeezed in muslin cloth to remove saliva (Langlands, 1975) and stored in airtight containers at -10 °C.

9.7.3 <u>Calculation of feed intake.</u> Estimates of DM and OM intake were obtained using expressions on p 26. Intake of DE (DEI) was determined as follows -

$$DEI = (GEh + GEg) - FE$$

where: GEh = gross energy of herbage consumed
(MJ/d, derived from energy
content of extrusa X DMI)

GEg = gross energy of grain consumed
(MJ/d)

FE = gross energy of faeces (MJ/d)

Metabolisable energy was taken to be 0.8DE (ARC, 1980).

9.7.4 <u>Sward sample measurements.</u> In Expt.A measurements made pre- and post-grazing each comprised 8 samples with cutting sites chosen on a stratified random basis. Herbage was cut to ground level with a shearing hand-piece on areas delineated by a 1/4 m quadrat. Procedures were similar in Expt.B except that a capacitance meter ("Charlie") was used to select cutting sites. Samples were bulked, mixed, washed to remove soil and faeces contamination and drained overnight. Total herbage weight was obtained and three 200 g samples taken by quartering for DM determination (dried to constant

weight at 80 °C), herbage dissection and laboratory measurements of nutritive value. The latter were stored in sealed polythene bags at -10 °C.

Mean herbage intake of allowance groups was calculated using the expression on p 27.

9.8 Wool production.

In both experiments greasy fleece weight was recorded prior to slaughter. More detailed measurement was made in Expt.A with mid-side samples of approximately 100 cm (Lockhart, 1954) clipped to skin level on all ewes during weeks 1 and 6 of lactation. Final samples were yield tested (clean weight/greasy weight) using standard procedures (weighed at 20 °C and relative humidity of 65%, I.W.T.O., 1976). Weight of greasy (GW, g/d) and clean wool (CW, g/d) produced during lactation was estimated from the ratio of mid-side sample weight (SB) to fleece weight and weight of final mid-side sample (H. Hawker, pers. comm.), i.e.

$$(1) \quad R = (SA + SB)/GFW$$
$$(2) \quad GW = (1/R \times SB/42)$$
$$(3) \quad CW = GW \times WY$$

where: SA = mid-side sample at the beginning
of lactation (g)

SB = mid-side sample at the end of
lactation (g)

GFW = greasy fleece weight (g)

WY = yield of final mid-side sample

9.9 Ewe body weights.

During pregnancy ewes were weighed weekly after being fasted overnight. Initial body weight post-partum was taken following a 6-8 h fasting period but during lactation body weights were recorded off pasture.

9.10 Body composition.

Ewes were fasted for 18 h then shorn and weighed just prior to slaughter. Killing was done by simultaneous severing of the blood vessels and dislocation of the neck. Blood was collected and the alimentary tract removed and emptied of contents. The alimentary tract, its contents, reticulo-rumen, blood, liver, kidneys, kidney fat (including perinephric and fascial), omental fat, dissected udder (mammary gland) and gravid uterus (in ISG groups) were individually weighed. All components and blood were stored in a sealed polythene bag at -10 °C.

Each frozen empty body was reduced to small fragments (approximately 5 X 2 cm) in a large industrial bone pulverisor then minced 3 times using an Autio cutter grinder (Autio Co., model 801HP, Astoria, U.S.A.) with 6 mm plate apertures. A representative aliquot of the homogenate (approximately 1 kg) was stored in a sealed polythene bag at -10 °C.

Fleece-free empty body weight was taken as the difference between shorn body weight prior to slaughter and contents of the alimentary tract. Any weight losses during slaughter and processing were assumed to be water.

9.11 Laboratory measurements.

9.11.1 Herbage dissection. Herbage dissection was done on freshly cut sward samples. Approximately 400 pieces were separated by quartering then divided into botanical species and dead material. Individual fractions were dried to constant weight at 80 °C and weights of DM expressed as proportions of the total.

9.11.2 Determination of DM. Samples of herbage, extrusa, faeces and mince homogenate were freeze dried to constant weight and milled according to A.O.A.C. (1960) standards. Routine checks were made' at the time of analysis for residual moisture by drying samples to constant weight at 80 °C. These and all subsequent determinations were done on duplicate samples.

9.11.3 In-vitro digestibility. The two stage method of Tilley and Terry (1963) was used on .5 g DM samples of cut herbage and extrusa. Samples of known in-vivo D were included as standards. Values of OMD for extrusa were corrected for loss of OM in saliva (Langlands, 1975).

9.11.4 Herbage protein (N X 6.25). The N content of cut herbage samples was determined on .5 g DM using a Kjeltec Digestion System (Hoganas, Sweden), with a 19:1 K_2SO_4:$CuSO_4$ catalyst, and an automatic titration unit (Multi-Dosimat E 415, Metrohm, Herisau, Switzerland).

9.11.5 Chromic oxide. Faecal DM samples weighing .5 g were incinerated in a muffle furnace at 450 °C for 12 h and the Cr_2O_3 content of ash determined after permanganate digestion (Williams et al., 1962) by Atomic Absorbtion Spectrophotometry (Model IC 151,

Instrumentation Laboratory Inc., Massachusetts, U.S.A.).

9.11.6 <u>Energy determinations.</u> The energy content of 1 g DM samples of cut herbage, extrusa herbage, faeces, milk and mince samples was measured using an Adiabatic Bomb Calorimeter (Model CB-110, A. Gallenkamp and Co. Ltd., London, England).

9.11.7 <u>Milk composition.</u> Fat content was measured on fresh milk samples using a Milko-Tester Minor 1800 (A/S N. Foss Electric, Hillerod, Denmark) and total solids on 1 ml samples by slow drying in a Total Solids Milk Tester (Wedholms, Nykoping, Sweden). Samples were stored at -10 °C and protein content (N X 6.38) subsequently determined on 5 ml aliquots (Expt.A) or .5 g freeze dried material (Expt.B) using the Kjeldahl method. Ash content was determined by incineration in a muffle furnace for 8 h at 550 °C. Lactose was obtained by difference (i.e. lactose = total solids - [fat + protein + ash]).

9.11.8 <u>Body composition.</u> Fat content of 3 - 4 g dried mince samples was determined by extraction for 6 h with di-ethyl ether using a Soxhlet apparatus. Protein content (N X 6.25) was measured on .5 g samples by the Kjeldahl method and ash determined by incineration of 5 g samples in a muffle furnace for 12 h at 575°C.

9.12 <u>Statistical methods.</u>

The data were analysed using the general statistical package, Genstat (Rothamsted Experimental Station, England).

All data collected during the lactation period were subjected to analysis of variance using a 2 X 3 factorial design. The significance of differences between individual means was determined by "t" test and errors given in the text are standard errors of means. Separate models were used for suckled and machine-milked groups in Expt.B. In addition, sequential measurements of feed intake, ewe and lamb body weight and milk production, were analysed using fourth order polynomials (Rowell and Walters, 1976). Linear and non-linear components of treatment interactions (pregnancy allowance X lactation allowance X time) lacked homogeneity so error terms for treatment group X time interactions were tested against error terms of second order interactions.

Regression equations were derived from data from post-partum slaughter groups, to predict empty body weight, body composition and energy content of live animals at the beginning of lactation from fasted body weight at that time.

During lactation the partitioning of MEI between body maintenance requirement and milk energy output, and the contribution of body tissue energy to milk synthesis, was achieved using methods outlined on p.7 and the following model -

$$MEI = b1MEBW + b2MKE - b3TSE$$

where - MEI = metabolizable energy intake (MJ/d)

MEBW = mean metabolic empty body weight ($EBW^{.75}$, kg)

MKE = milk energy (MJ/d)

TSE = body tissue energy (MJ/d)

RESULTS

(Experiment A)

Air temperatures and rainfall each week during pregnancy and lactation are shown in Fig. 9.5.

9.13 Pasture measurements during pregnancy and lactation.

9.13.1 Quantity and nutritive value of herbage. Mean values for herbage mass, botanical composition, D, CP and GE contents of sward samples before grazing are given in Table 9.2. Measurements indicate that nutritional value was greater on average during lactation than during pregnancy. During lactation (Fig. 9.6) herbage mass varied between 2,500 and 5,500 kg DM/ha. The proportion of green material (grass + clover) in the sward prior to grazing and in-vitro D declined as lactation progressed.

9.13.2 Herbage utilization. Herbage allowance and apparent intake (not corrected for herbage growth) during pregnancy and lactation, are given in Table 9.3.

Apparent intake of the H- group during mid- and late-pregnancy respectively, was 100% and 13% higher than the L- group. During lactation ewes in the -H group apparently consumed 18% more DM than those in -L and -M groups.
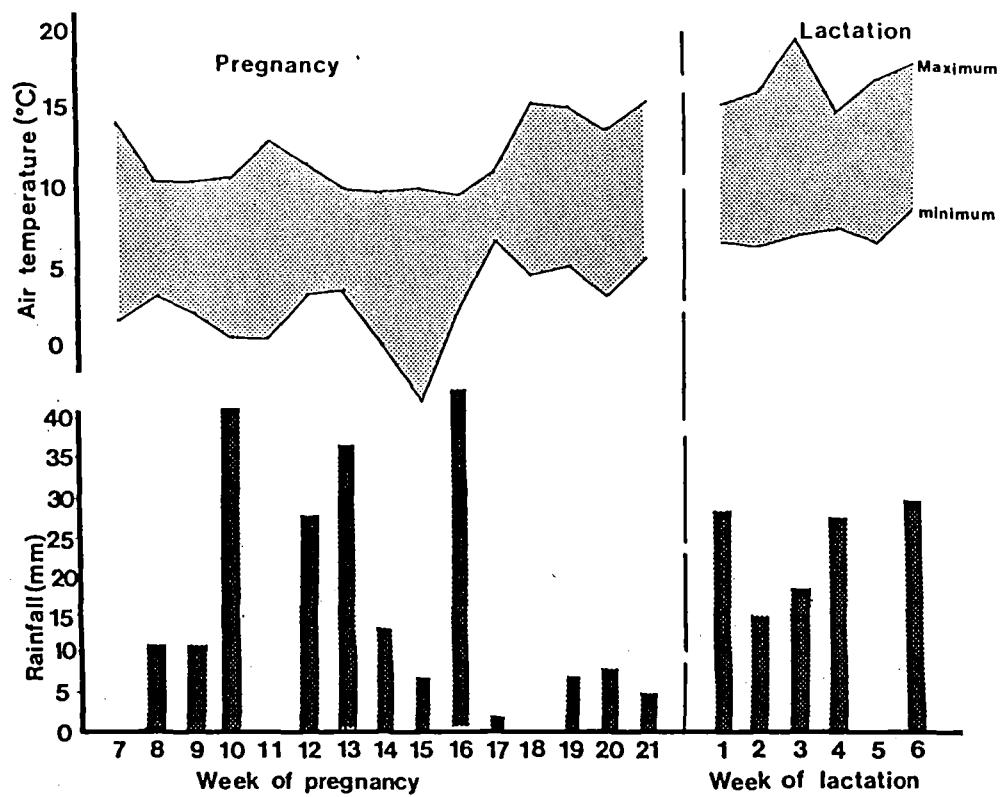
Figure 9.5: Variation in daily air temperatures and total rainfall during pregnancy and lactation (Expt. A).
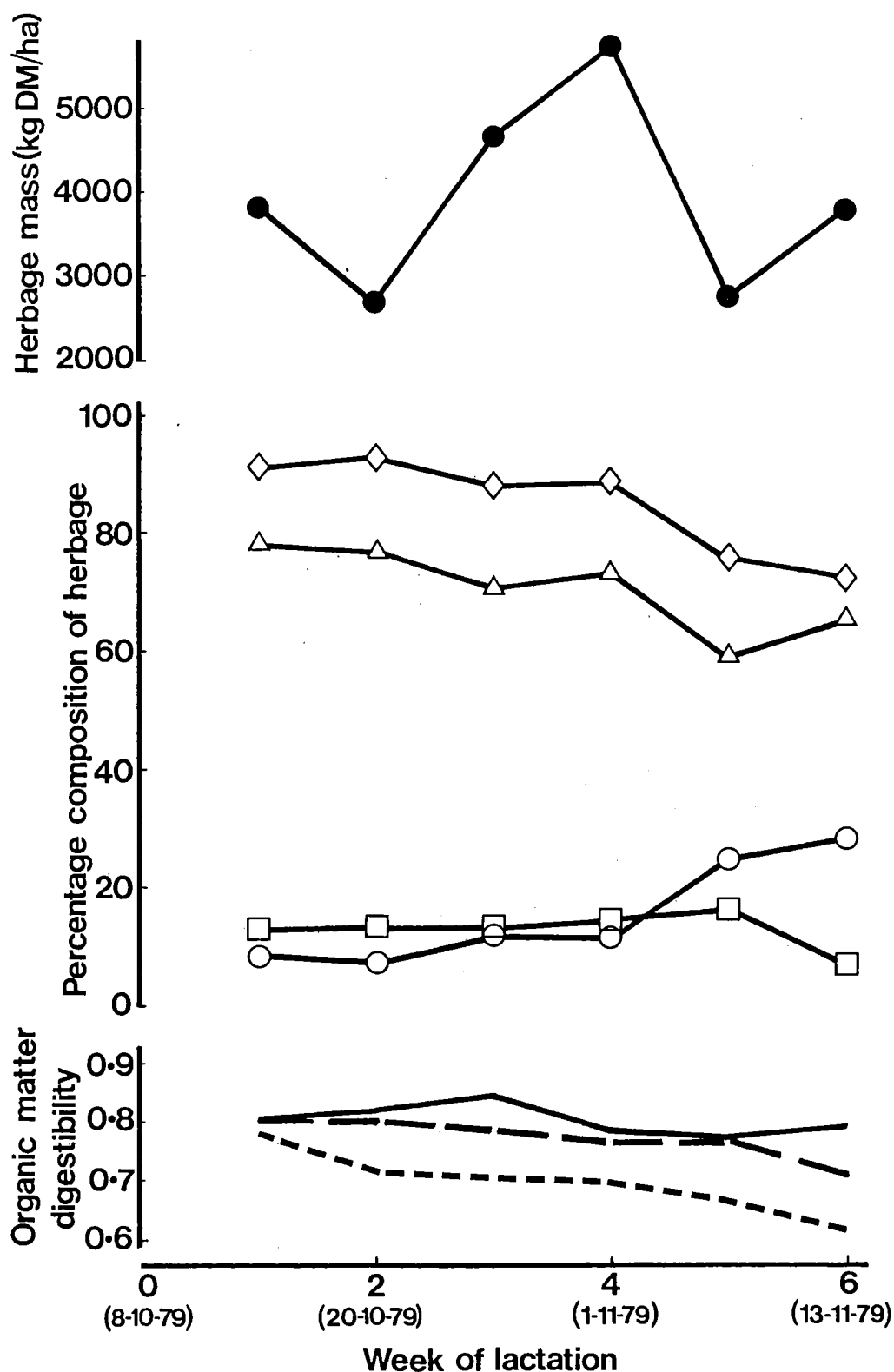
Figure 9.6: Mean values during lactation for pre-grazing herbage mass, ●——● ; botanical composition of herbage (green material, ◇——◇ ; grass, △——△ ; clover, □——□ ; dead material, ○——○) and digestibility (OMD) of herbage pre-grazing, ——— ; post-grazing, ······ ; and of extrusa, —— (Expt. A).

Table 9.2 Mean values for herbage mass (kg DM/ha), percentage botanical composition, crude protein (N X 6.25), gross energy content (MJ/kg DM) and digestibility of the sward before grazing during pregnancy (n = 24) and lactation (n = 16) (Expt.A)

	Pregnancy			Lactation	
	L-	H-	SD		SD
Herbage mass	1410	2160	1066.7	3690	910.3
Botanical composition-					
grass	60	68	8.2	72	6.9
clover	12	11	3.8	13	3.2
green material	72	79	11.9	85	10.2
dead material	24	16	9.1	13	7.7
Digestibility-					
DMD	.64	.69	.065	.76	.056
OMD	.69	.74	.058	.77	.050
Crude protein content+	199	199		174	
Gross energy content+	16.6	17.4		17.2	

+ estimated on 30% of samples

Table 9.3   Grazing intensity (number of ewes/ha), herbage allowance (kg DM/ewe/d), post grazing herbage mass (kg DM/ha) and apparent dry matter intake (kg DM/ewe/d) for allowance groups during pregnancy and lactation (Expt.A)

Period	Pregnancy				SD	Lactation			SD
Herbage allowance group	L-		H-			-L	-M	-H	
Grazing intensity	386		289			561	221	141	
Stage of pregnancy	mid+	late+	mid+	late+					
Number of observations	18	6	17	7		16	16	16	
Herbage allowance	0.93	2.55	2.13	3.66	0.845	2.27	5.70	9.04	
Post-grazing herbage mass	440	990	875	1730	386.7	1590	2810	2970	556.2
Apparent intake of DM	0.43	1.66	0.97	1.87	0.615	1.23	1.20	1.44	0.845

+ mid - weeks 6-16 of pregnancy; late - weeks 17-21 of pregnancy

9.14 <u>Diet</u> <u>quality,</u> <u>individual</u> <u>feed</u> intake <u>during</u> <u>lactation</u> and <u>milk</u> <u>production.</u>

9.14.1 <u>Nutritive</u> <u>value</u> <u>of</u> <u>diets.</u> Mean D of extrusa (n=103) from O/F ewes ($\bar{x}$DMD .780; $\bar{x}$OMD .793, SD= 0.046) was similar among groups, values being slightly greater than that for the sward prior to grazing (Table 9.2 and Fig. 9.6). On average, extrusa contained 17.5 MJ GE/kg DM and 11.2 MJ ME/kg DM.

9.14.2 <u>Correction</u> <u>factors</u> <u>for</u> Cr_2O_3 <u>concentration</u> <u>in</u> <u>faeces.</u> The recovery of Cr_2O_3 in total faecal collections was $98.4 \pm 1.88\%$ and did not vary significantly between intake periods or treatment groups. The ratio of Cr_2O_3 in total collections:grab samples was $1.14 \pm .030$ and similar in all periods (Fig. 9.7). Concentration of Cr_2O_3 in all grab samples was therefore increased by 14%.

9.14.3 <u>Feed</u> <u>intake.</u> Mean daily OMI for groups during each 6 d period are shown in Fig. 9.8. Ewes in each group achieved maximum intake during weeks 3 and 4 (i.e. periods 2-3) of lactation before showing a gradual decline to week 6. There were no significant differences in trends with time between treatments.

Mean values during lactation for OMI and MEI are given in Table 9.4.

A significant interaction indicated that L- ewes on -L and -H allowances had greater intakes of OM and ME than H- ewes while the effect was reversed on the -M allowance. Expression of intake per kg $W^{.75}$ showed that L- ewes had a
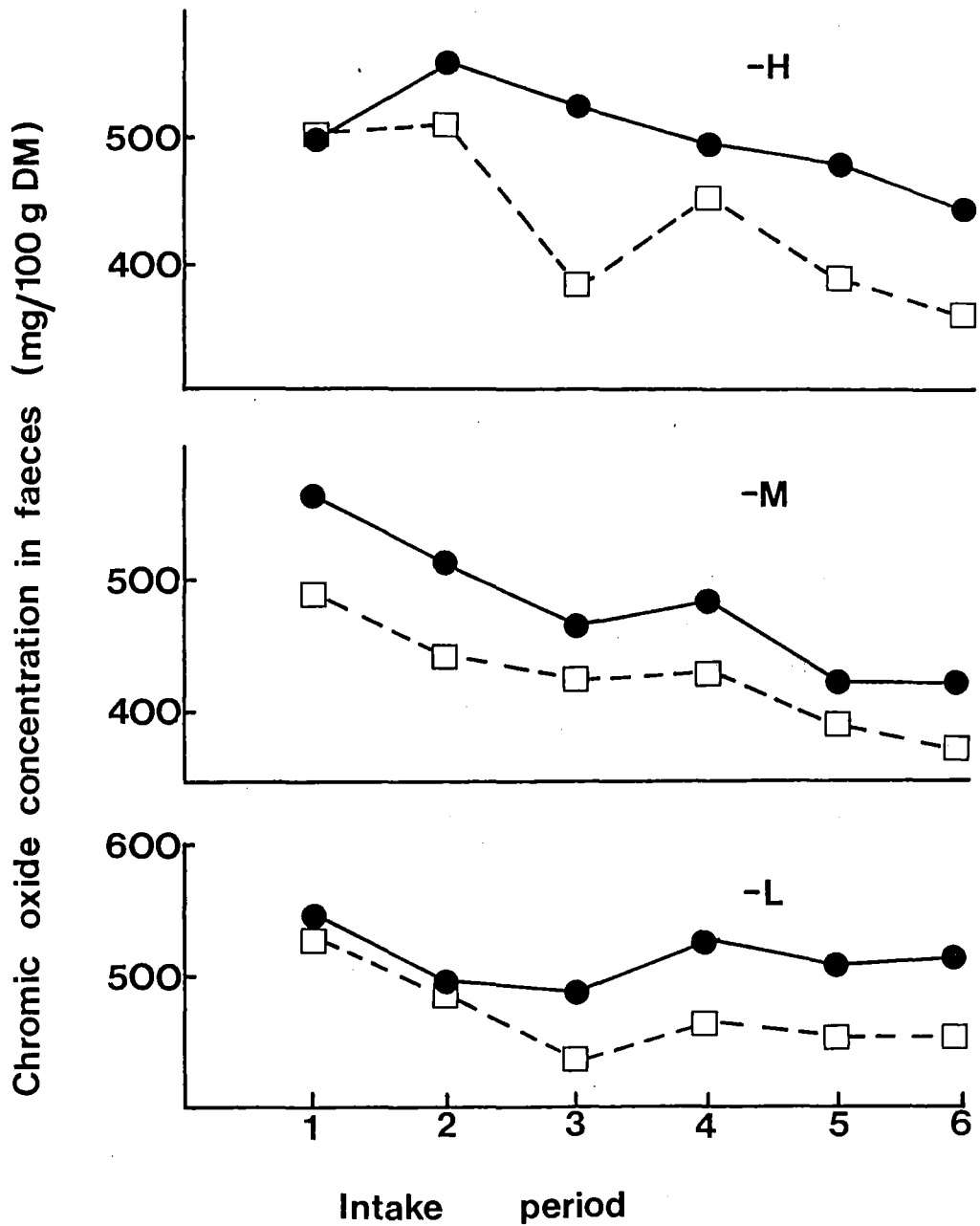
Figure 9.7: Chromic oxide concentration in faeces from total collections, ●———● and grab samples, □- - -□ taken from ewes bagged for total collection (Expt. A).
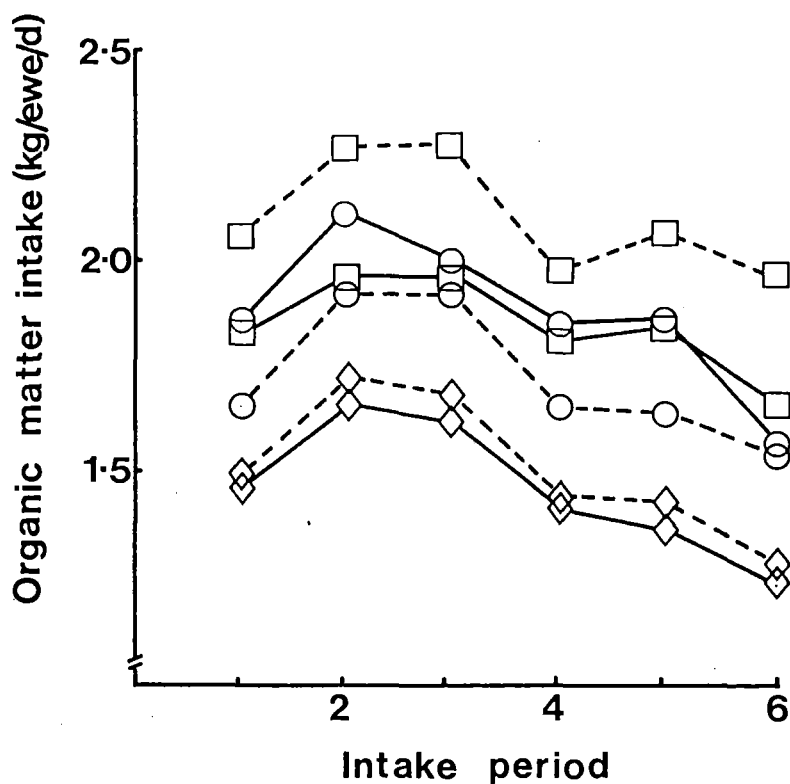
Figure 9.8: Mean daily OM intake during lactation
in LL, ◇- - -◇ ; HL, ◇——◇ ; LM,
O- - -O ; HM, O——O ; LH, □- - -□ ;
and HH, □——□ treatment groups (Expt.A).
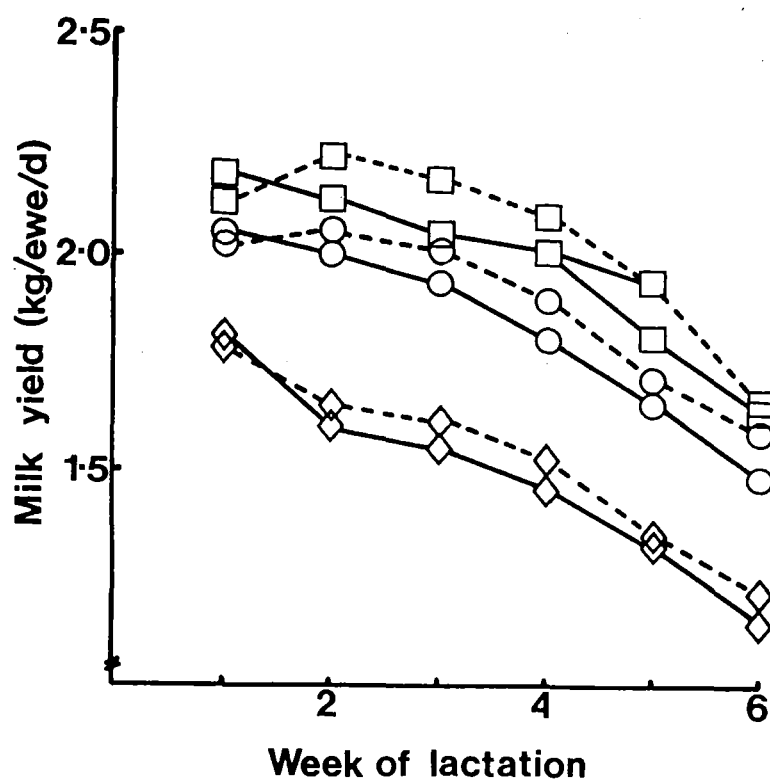
Figure 9.9: Mean daily milk production in LL, ◇- - -◇ ;
HL, ◇——◇ ; LM, O- - -O ; HM, O——O ;
LH, □- - -□ ; and HH, □——□ treatment
groups (Expt. A).

Table 9.4   Effects of herbage allowance during pregnancy and lactation on daily intake of organic matter (OM), digestible organic matter (DOM) and metabolizable energy (ME) during the first 6 weeks of lactation (Expt.A)

	Pregnancy allowance		Lactation allowance			Individual treatments						SD	Significance tests		
	L-	H-	-L	-M	-H	LL	HL	LM	HM	LH	HH		pregnancy eff.	lactation eff.	interaction
Number of ewes	32	36	23	22	23	11	12	10	12	11	12				
OM intake- kg/d	1.78	1.72	1.48	1.81	1.96	1.51	1.46	1.72	1.87	2.09	1.84	0.215	NS	**	**
DOM intake- g/kg $W^{.75}$	71	63	58	69	73	63	54	70	68	81	66	9.6	**	**	NS
ME intake- MJ/d	22.4	21.5	19.4	22.4	24.1	19.8	19.0	21.5	23.1	25.8	22.6	2.52	NS	**	**
kJ/kg $W^{.75}$	1126	983	952	1074	1127	1032	881	1100	1047	1244	1021	142.7	**	**	NS

14% greater intake compared with H- ewes; -M and -H groups averaged respectively, 23% and 16% greater daily intakes of DOM and ME compared with the -L allowance.

Mean daily intake of grain offered to ewes during milking averaged 47 g/ewe and this contributed about 3% (.646 MJ ME/d) to total daily ME intake.

9.14.4 <u>Milk production.</u> Mean daily milk production (Fig. 9.9) was maximal during week 2 of lactation in LH and LM groups and during week 1 for remaining groups. Low allowance groups showed a comparatively rapid decline in milk production between weeks 1 and 2 before following a similar declining trend to the other groups until week 6 of lactation. There were no significant differences in linear trends with time between treatment groups but quadratic trends were different (P<0.05) between -L and -H groups.

Mean values for daily milk production during the 6 weeks of lactation (Table 9.5) were 23% and 33% higher, respectively, in -M and -H compared with the -L group. Mean daily production per kg $W^{.75}$ showed corresponding differences of 20% and 27% and a 14% greater yield in L- compared with H- ewes.

Changes in milk composition (Fig. 9.10) generally showed similar trends for each allowance group. Fat content fluctuated between weeks but showed little change with time as did protein. Lactose and total solids gradually declined as lactation progressed.

The relationship between total milk solids (X, g/kg) and milk energy content (Y, MJ/kg) was examined in

Table 9.5 Effects of herbage allowance during pregnancy and lactation on mean daily milk production, milk composition and energy content during the first 6 weeks of lactation (Expt.A)

	Pregnancy allowance		Lactation allowance			Individual treatments						SD	Significance tests		
	L-	H-	-L	-M	-H	LL	HL	LM	HM	LH	HH		pregnancy eff.	lactation eff.	interaction
Number of ewes	32	36	23	22	23	11	12	10	12	11	12				
Milk yield-															
kg/d	1.81	1.75	1.50	1.85	2.00	1.53	1.48	1.88	1.82	2.04	1.97	0.386	NS	**	**
g/kg W$^{.75}$/d	91	80	74	89	94	79	69	95	83	99	90	18.6	*	**	NS
Milk composition (g/kg)-															
fat	67	67	71	65	66	71	72	65	65	66	65	6.4	NS	**	NS
protein (NX6.38)	53	53	53	53	53	54	52	52	54	54	52	3.6	NS	NS	NS
lactose	51	50	51	50	50	53	50	51	49	49	51	5.3	NS	NS	NS
total solids	181	180	186	178	179	187	184	177	178	179	179	8.7	NS	**	NS
Milk energy-															
MJ/kg	4.9	4.8	5.0	4.8	4.8	5.0	4.9	4.7	4.8	4.8	4.8	.24	NS	**	NS
kJ/kg W$^{.75}$/d	438	386	364	421	447	395	339	451	395	471	428	87.0	*	**	NS
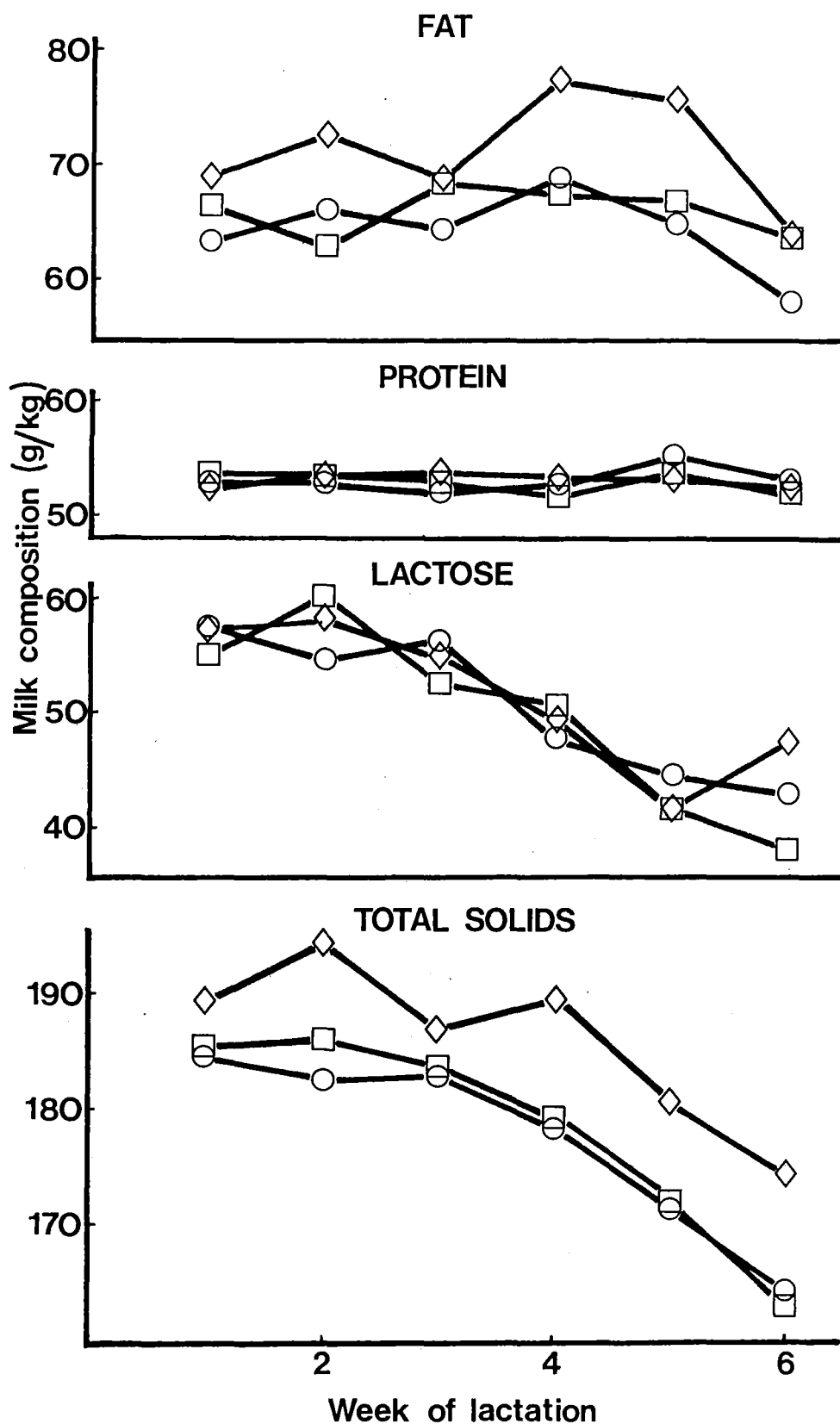
Figure 9.10: Mean milk composition for ewes in -L, ◇——◇ ; -M, O——O ; and -H, □——□ herbage allowance groups (Expt. A).

approximately 7 milk samples from each allowance group during weeks 2, 4, and 6 of lactation (Fig. 9.11). The regression equation (n=66) was as follows-

$$Y = 0.0278 \ X - 0.184 \quad RSD = 0.300 \ r^2 = 0.85$$

There was no effect of herbage allowance or stage of lactation and the relationship has been used to predict the energy content of all remaining milk samples.

Milk from ewes offered the -L allowance had greater concentrations (Table 9.5) of fat, total solids and increased energy compared with that from ewes in -M and -H groups. Daily energy yield per kg $W^{.75}$ was 16% and 23% greater, respectively, for -M and -H compared with -L groups and 13% greater for L- compared with H- ewes.

There were no significant treatment interactions for milk yield or composition.

9.15 Body weight and body composition of ewes.

9.15.1 Body weight. Low and high herbage allowances during pregnancy resulted in mean differences of 13.6 and 10.7 kg, respectively, immediately pre- and post-partum (Fig. 9.12). Body weight of ewes in all treatments, especially those in L- groups, showed increases during the initial 2 weeks of lactation then declined until week 6. The decline tended to be greater
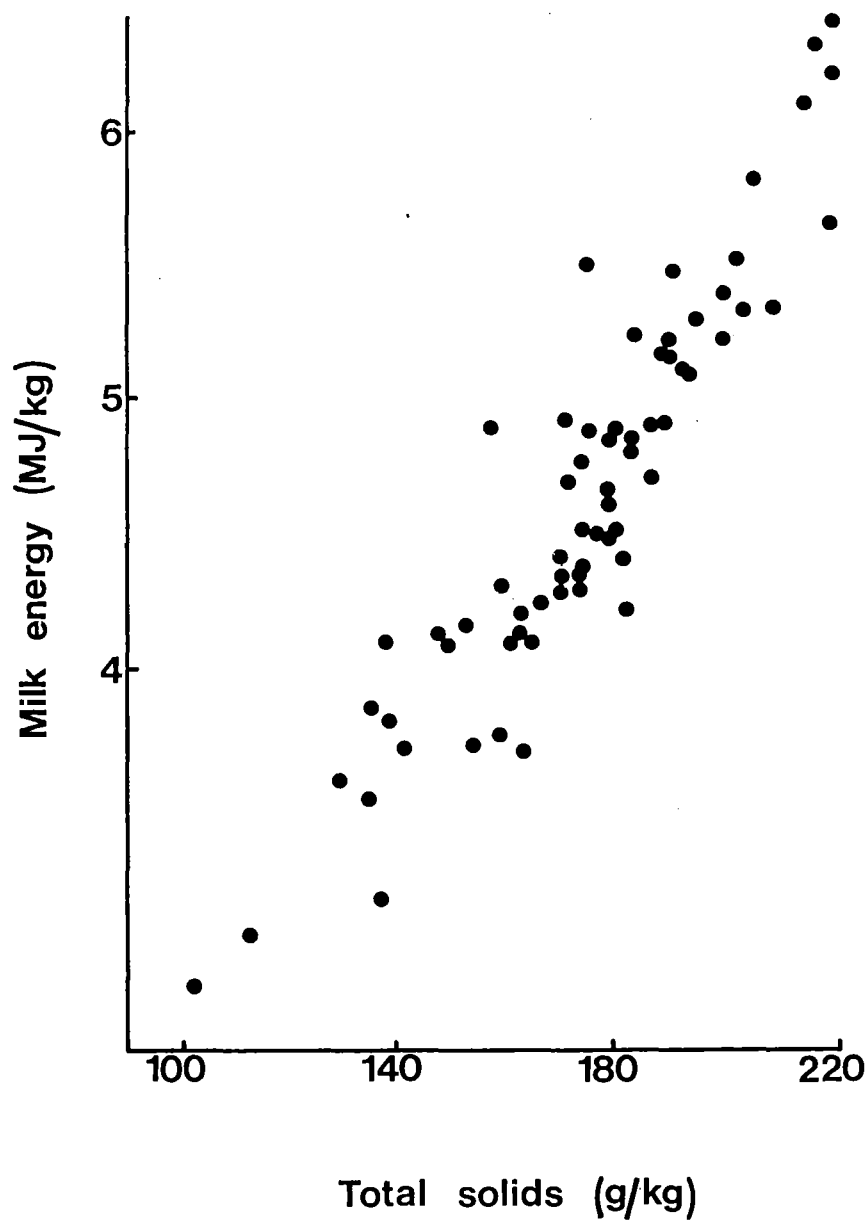
Figure 9.11:   Relationship between milk energy and
               total milk solids in a sample of ewes
               from each herbage allowance group at
               three stages during lactation (Expt. A).
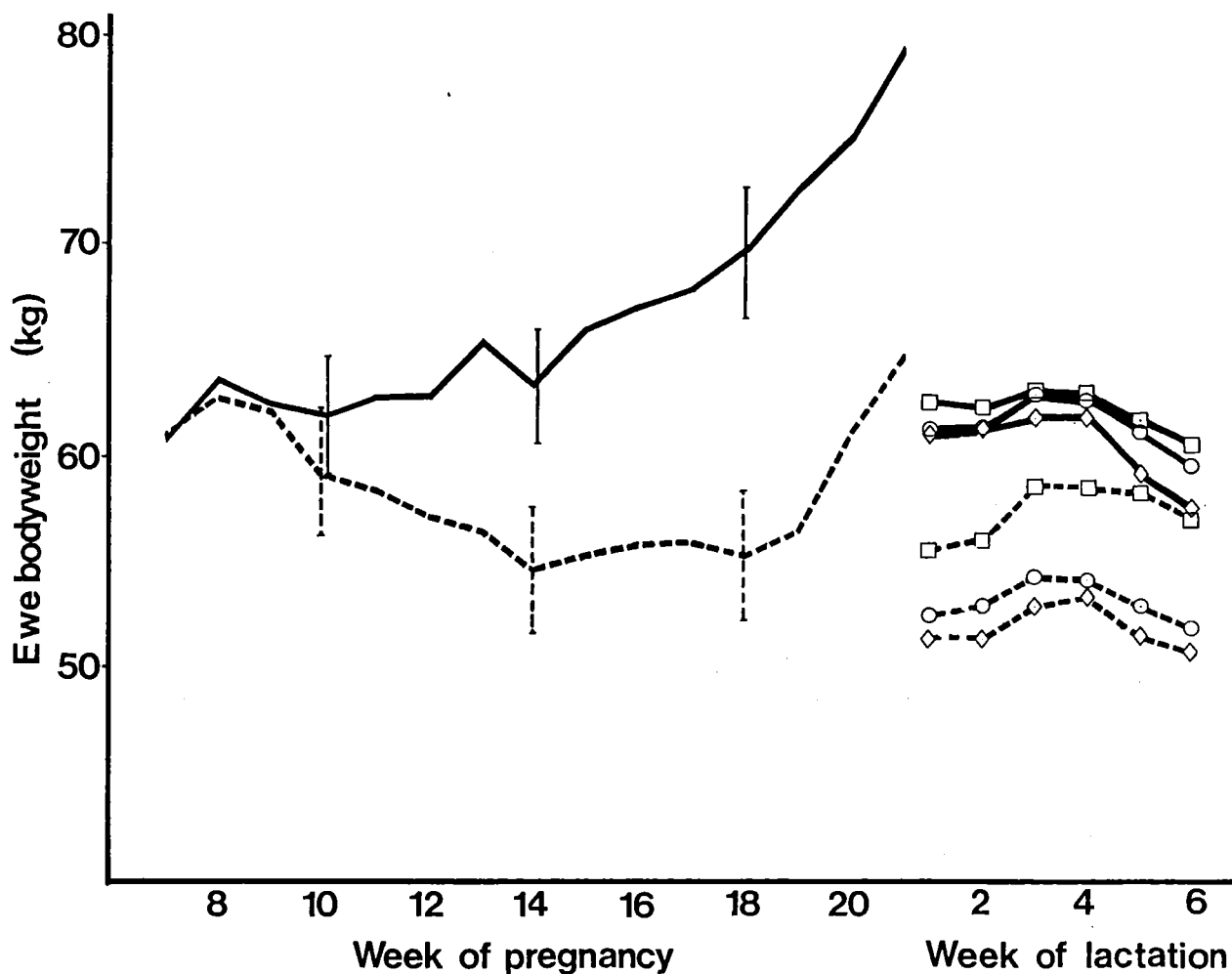
Figure 9.12:   Mean body weights of ewes during pregnancy
in L-,---- ;   and H-, ⸺ groups (I - SD)
and during lactation in LL, ◇- --◇ ;
HL, ◇⸺◇ ; LM, O- --O ; HM, O⸺O ;
LH, □- --□ ; and HH, □⸺□ groups
(Expt. A).

for H- than L- ewes and greater for ewes on the -L compared with -H allowance. A significant (P<0.05) pregnancy X lactation allowance interaction indicated that differences in body weight between L- and H- ewes on -L and -H allowances became progressively smaller during lactation compared with little corresponding change on the -M allowance.

Mean ewe body weights during weeks 2, 4 and 6 of lactation are given in Table 9.6. There were no significant treatment interactions for mean ewe body weight.

9.15.2 Weights of body parts. Mean weights of body parts in ewes slaughtered during early pregnancy, post-partum and after 6 weeks of lactation are set out in Table 9.7. There were no significant pregnancy X lactation treatment interactions in any of the variables.

Weight of the reticulo-rumen decreased by 17% during pregnancy in the L- group but thereafter showed little change. By week 6 of lactation mean reticulo-rumen weight in the -H group was on average 11% greater than in -L and -M groups. In contrast, there was a slight increase in weight of the complete alimentary tract of both groups during pregnancy, then a small decrease by week 6 of lactation when the difference between -L and -H groups was 15%. Weight of digesta (recorded following fasting) showed a 10% reduction between early pregnancy and post-partum in H- ewes, but, on average, increased by 41% by the end of lactation in all groups.

Table 9.6 Effect of herbage allowance during pregnancy and lactation
on body weight (kg) of ewes during the first six weeks of
lactation (Expt.A)

| | Pregnancy allowance | | Lactation allowance | | | SD | Significance tests | |
| | | | | | | | Pregnancy | Lactation |
	L-	H-	-L	-M	-H		effects	effects
Number of animals	32	38	24	23	23			
Body weight –								
post-partum	50.1	60.8	55.8	55.8	56.1	6.78	**	NS
week 2	53.4	61.5	56.4	57.8	59.3	6.73	**	NS
week 4	55.3	62.2	58.0	58.9	61.0	6.63	**	NS
week 6	53.2	59.6	54.5	56.7	58.9	6.79	**	NS
mean+	54.3	61.5	56.6	57.9	60.2	6.65	**	NS

+ means do not include post-partum weight

Table 9.7 Effects of herbage allowance during pregnancy and lactation on weights of body components of ewes (kg) immediately post-partum, after six weeks of lactation and of controls slaughtered in early pregnancy (Expt.A)

When slaughtered	Early pregnancy		Post-partum				Week 6 of lactation						Significance tests	
Slaughter group	ISG		L-	H-			L-	H-	-L	-M	-H			
Main effect			Pregnancy allowance				Pregnancy allowance		Lactation allowance				Pregnancy effects	Lactation effects
Number of ewes	10	SD	11	9	SD	Signif.	32	38	24	23	23	SD	effects	effects
Pre-slaughter body weight	58.9	3.88	46.2	58.8	6.79	**	48.8	54.5	50.4	51.5	53.8	6.47	**	NS
Empty body	54.3	4.16	41.7	54.6	6.36	**	42.4	48.5	43.9	45.6	47.8	5.83	**	NS
Reticulo-rumen	1.48	0.273	1.23	1.52	0.215	**	1.37	1.42	1.32	1.38	1.50	0.204	NS	**
Alimentary tract	2.89	0.298	3.13	3.34	0.464	NS	2.86	2.79	2.64	2.80	3.03	0.485	NS	**
Alimentary tract contents	4.60	1.094	4.55	4.15	1.102	NS	6.35	5.95	6.47	5.90	6.00	1.511	NS	NS
Liver	0.863	0.106	1.007	1.191	0.115	**	0.939	0.958	0.827	0.954	1.072	0.1153	NS	**
Kidneys	.162	.006	.171	.193	.021	NS	.161	.162	.151	.162	.171	0.017	NS	**
Udder	0.35	0.070	2.28	2.31	0.854	NS	1.46	1.48	1.30	1.49	1.61	0.320	NS	**
Greasy fleece	1.81	0.234	1.93	2.62	0.426	**	2.00	2.35	2.11	2.23	2.24	0.372	**	NS
Litter at birth			7.36	7.29	2.511	NS	6.82	8.14	7.89	7.41	7.32	1.945	**	NS

Liver weight increased by 38% and 17% during pregnancy in H- and L- ewes respectively, but generally decreased during lactation. Livers of -M and -H groups were, respectively, 30% and 15% heavier than those of the -L group by week 6 of lactation.

Kidney weight increased by 12%, on average, during pregnancy but then showed a similar average decline by the end of lactation.

The weight of dissected udder increased six-fold between early pregnancy and post-partum and by week 6 of lactation had regressed by 43%, 35% and 30% respectively in -L, -M and -H groups.

There was no difference in mean litter birth weight between post-partum slaughter groups but mean values for the remaining ewes were 16% greater for H- compared with L- groups. Mean litter sizes for all ewes lambing were, respectively, 1.71 and 1.79 $\pm$ 0.608 for L- and H- groups.

9.15.3 Wool growth. Greasy fleece weight of H- and L- ewes increased by 45% and 7%, respectively, during pregnancy. Greasy fleece weight of all groups remained unchanged during lactation though mid-side patches showed that wool growth was similar amongst groups at 4.5 $\pm$ 1.26 and 2.9 $\pm$ 0.92 g/d, respectively, for greasy and clean wool. This represents a total of 190 g greasy wool growth (an increase of about 8%) during lactation.

9.15.4 Chemical composition and energy content. The chemical composition and body energy content of ewes slaughtered during early pregnancy, post-partum and after 6 weeks of lactation, are shown in Table 9.8. There were

Table 9.8 Effects of herbage allowance during pregnancy and lactation on gross chemical composition and energy content of the bodies of ewes immediately <u>post-partum</u> and after six weeks of lactation and of controls slaughtered in early pregnancy (Expt.A)

When slaughtered	Early pregnancy		Post-partum				Week 6 of lactation						Significance tests	
Main effect			Pregnancy allowance				Pregnancy allowance		Lactation allowance				Pregnancy effects	Lactation effects
Group	ISG	SD	L-	H-	SD	Signif.	L-	H-	-L	-M	-H	SD		
Fat weights (kg)														
kidney+	1.28	0.478	0.39	0.80	0.328	**	0.39	0.65	0.42	0.53	0.65	0.352	**	NS
omental+	2.36	1.125	0.88	1.68	0.608	**	0.78	1.27	0.86	1.05	1.23	0.569	**	NS
carcass+	13.30	2.382	6.72	12.25	2.938	**	6.40	9.87	7.57	8.35	8.96	2.939	**	NS
total*	16.90	3.770	8.00	14.73	3.788	**	7.56	11.79	8.84	9.92	10.85	3.733	**	NS
Weights of components (kg)														
water	28.25	1.325	25.70	30.20	2.282	**	26.71	27.88	26.74	27.17	28.14	2.690	NS	NS
protein	7.24	0.499	6.18	7.68	0.739	**	6.39	6.98	6.51	6.74	6.90	0.693	**	NS
ash	1.88	0.188	1.80	2.02	0.236	NS	1.76	1.86	1.79	1.77	1.88	0.200	*	NS
Ratios of components														
internal/total fat	.206	.049	.142	.166	.0399	NS	.135	.155	.133	.148	.156	.0455	NS	NS
water/FFEB		.756	.0082	.764	.757	.0080	NS	.766	.761	.763	.764	.762	.0109	*	NS
protein/FFEB		.194	.005	.183	.193	.0080	**	.184	.190	.186	.189	.187	0.291	NS	NS
ash/FFEB		.050	.0037	.053	.051	.0040	NS	.051	.051	.051	.049	.051	.0083	**	NS
water/protein	3.91	.150	4.18	3.94	.211	*	4.18	4.05	4.12	4.12	4.09	.0040	NS	NS
Body energy-														
MJ/kg EBW	15.11	1.928	10.38	13.43	1.971	**	9.82	12.42	10.69	11.38	11.64	2.436	**	NS
total (MJ)	826	156.8	442	743	164.9	**	428	610	482	529	571	159.4	**	NS

+ weight of dissected fat depot

* weight of chemically determined fat

no significant treatment interactions.

During pregnancy ewes in L- and H- groups lost 53% (90 g/d) and 13% (26 g/d) of total body fat content respectively. Losses during lactation tended to be greater in H- (93 g/d) compared with L- ewes (63 g/d). Mobilization of fat during pregnancy and lactation were proportionately greater from internal depots than from the rest of the body. Internal fat comprised 21%, 15% and 14% of total fat during early pregnancy, post-partum and at the end of lactation, respectively.

During pregnancy total body water and protein contents were reduced (9% and 15% respectively) in the L- group and increased (6% in both cases) in the H- group. Changes in water and protein weights during lactation were small and similar on all lactation treatments. Weight of ash showed little change during pregnancy or lactation.

Concentrations of components in the FFEB during pregnancy and lactation were relatively constant (Table 9.8). Water averaged 760 g/kg and ash varied little from 50 g/kg. Protein concentration was greater in H- compared with L- ewes both at the beginning and end of lactation.

The energy content (Y, MJ/kg) of 3 ewes from each slaughter group, was regressed on fat content (X, g/kg) (Fig. 9.13). The regression equation (n = 27) was -

$$Y = 0.038 \ X + 3.236 \quad RSD = 0.030 \ r^2 = .99$$

and was used to estimate body energy content of all ewes slaughtered during pregnancy and lactation (Table 9.8). Body energy content of H- ewes was 41% greater than that of L- ewes post-partum. Changes in energy content during
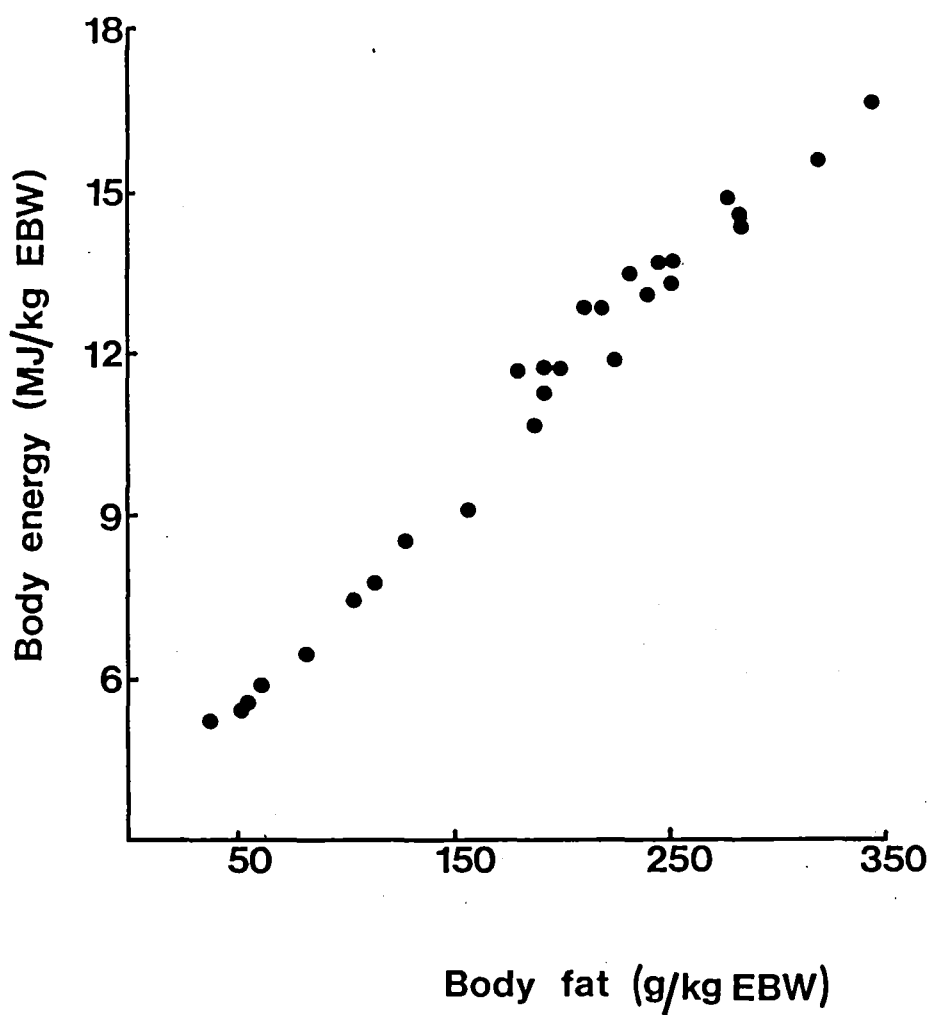
Figure 9.13: Relationship between body energy and
body fat content in three ewes from
each slaughter group (Expt. A).

lactation were greater in H- compared with L- ewes.

9.15.5 <u>Body composition of live ewes.</u> The relationship between pre-slaughter fasted (unshorn) body weight (X, kg) and EBW (Y, kg), for ewes slaughtered <u>post-partum</u> (n = 20), did not differ between L- and H- groups and was -

$$Y = 0.976 \ X - 3.157 \quad RSD = 1.100 \ r^2 = .99$$

The closeness of this relationship enabled direct prediction, from fasted body weight (X, kg), of body fat <u>post-partum</u> (Y, kg) in individual ewes in lactation groups. The relationship did not vary between L- and H- groups and the following regression equation, also derived in ewes slaughtered <u>post-partum</u>, was used -

$$Y = 0.524 \ X - 16.14 \quad RSD = 1.511 \ r^2 = .91$$

Similarly, prediction of body protein (Y, kg) was obtained from fasted body weight (X, kg) using the following regression equation derived in ewes slaughtered <u>post-partum</u> -

$$Y = 0.108 \ X + 1.26 \quad RSD = 0.350 \ r^2 = 0.90$$

Changes in weights of body protein and fat, between early pregnancy, <u>post-partum</u> (predicted values) and the end of lactation, are shown in Fig. 9.14. Ewes in the H- group gained about 5 g protein/d during pregnancy while L- ewes lost 5 g/d. During lactation negative protein balances were found, losses ranging from 2 (LH) to 26 g/d
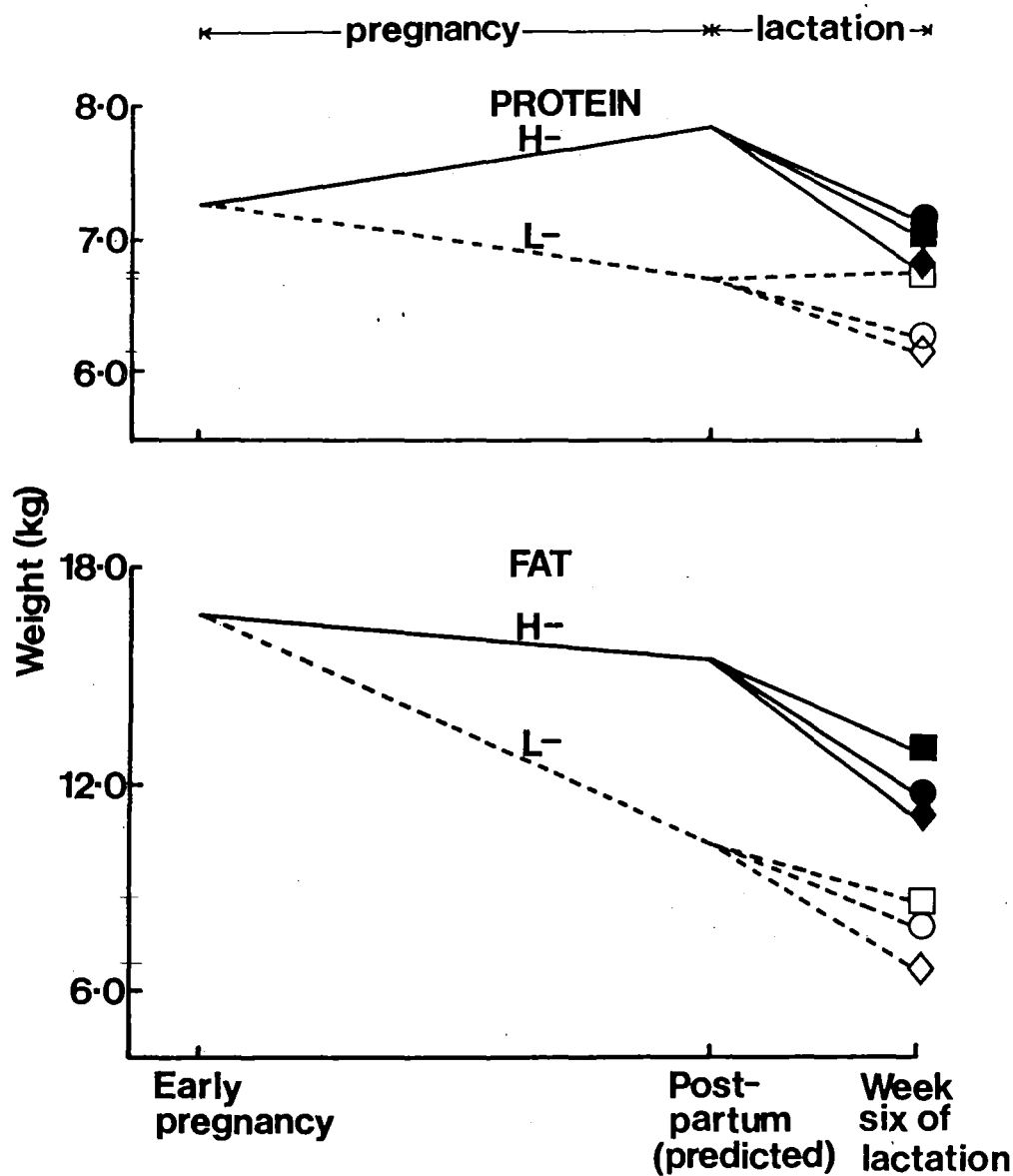
Figure 9.14: Predicted weights of body protein and fat
in L- and H- groups post-partum and actual
weights in LL, ◇ ; HL, ◆ ; LM, ○ ; HM, ● ;
LH, □ and HH, ■ groups slaughtered at week
6 of lactation (Expt. A).

(HL). Predicted body fat losses were 11 and 63 g/d for L-
and H- groups, respectively, during pregnancy and during
lactation ranged from 53 (LH) to 120 g/d (HL).

9.16 Utilization of energy during lactation.

9.16.1 Partitioning of energy. During the 6 week
lactation period the partitioning of mean MEI between MEm
and MKE output and the contribution of mobilised TSE to
milk synthesis, is shown in the following regression
equations for L- (n=32) and H- (n=35) ewes.

L- (pregnancy) MEI = 0.619 MEBW + 1.45 MKE - 0.337 TSE
                (SE) (.0638)   (.2203)   (.2102)
                     RSD = 1.975 r^2 = 0.68

H- (pregnancy) MEI = 0.728 MEBW + 1.05 MKE - 0.371 TSE
                (SE) (.0638)   (.1348)   (.1130)
                     RSD = 1.791 r^2 = 0.68

       where- MEI = mean metabolizable energy intake (MJ/d)
             MEBW = mean metabolic empty body weight (kg)
              MKE = mean milk energy production (MJ/d)
              TSE = mean body tissue energy mobilized (MJ/d)
               SE = standard errors of coefficients

     Correlation coefficients between independant
variables in the above regressions are set out in Table
9.9.

Correlations between variables were non-significant with
the exception of a negative correlation (P<0.05) between

TSE and MKE in the L- group.

Estimates of maintenance requirements (bMEBW), efficiency of utilization of ME above maintenance for milk synthesis, K_1 (1/bMKE) and efficiency of utilization of TSE for milk production (bTSE/bMKE) are given in Table 9.10.

Estimated maintenance requirement during lactation tended to be greater by about 18% for H- compared with L-ewes. Associated with this were 38% and 52% greater values, respectively, for K_1 and efficiency of use of energy from body tissue for milk synthesis.

Table 9.9 Correlation coefficients between independant
          variables in energy partitioning regressions
          (Expt.A)

	L-			H-	
Independant variables	TSE	MKE		TSE	MKE
MEBW	-.14	.34		-.20	.03
MKE	-.41			-.10	

Table 9.10 Estimates of maintenance energy requirement
           (MJ ME/ewe /d), efficiency of conversion of
           ME above maintenance to milk energy (K_1)
           and efficiency of utilization of body tissue
           energy for milk production by ewes offered
           low (L-) or high (H-) allowances during
           pregnancy (Expt.A)

	Maintenance requirement per kg			K_1	Tissue energy utilization
	MEBW	MBW	W		
L-	.619	.549	.205	.69	.23
H-	.728	.658	.236	.95	.35

RESULTS

(Experiment B)

Because of the similarity in design between the two experiments, results from Expt.B are presented in a similar way to those from Expt.A. The major difference in Expt.B is the use of twin-suckled ewes, with the inclusion of additional groups (LMm and HMm) of ewes machine-milked.

Air temperatures and rainfall each week during pregnancy and lactation are shown in Fig. 9.15.

9.17 Pasture measurements during pregnancy and lactation.

9.17.1 Quantity and nutritive value of herbage. Mean values for herbage mass, botanical composition, D, CP and GE contents of sward samples before grazing are given in Table 9.11 and Fig. 9.16. During lactation there was a progressive decline in herbage mass from 2,900 to 1,800 kg DM/ha. The proportion of green material in the sward prior to grazing and in-vitro D also declined as lactation progressed.

9.17.2 Herbage utilization. Allowances and apparent intakes during pregnancy and lactation are given in Table 9.12.

Herbage allowances during mid- and late- pregnancy (final 4 weeks) caused three-fold and 77% respectively, greater apparent intake for H- compared with L- groups. There was little effect of herbage allowance on apparent
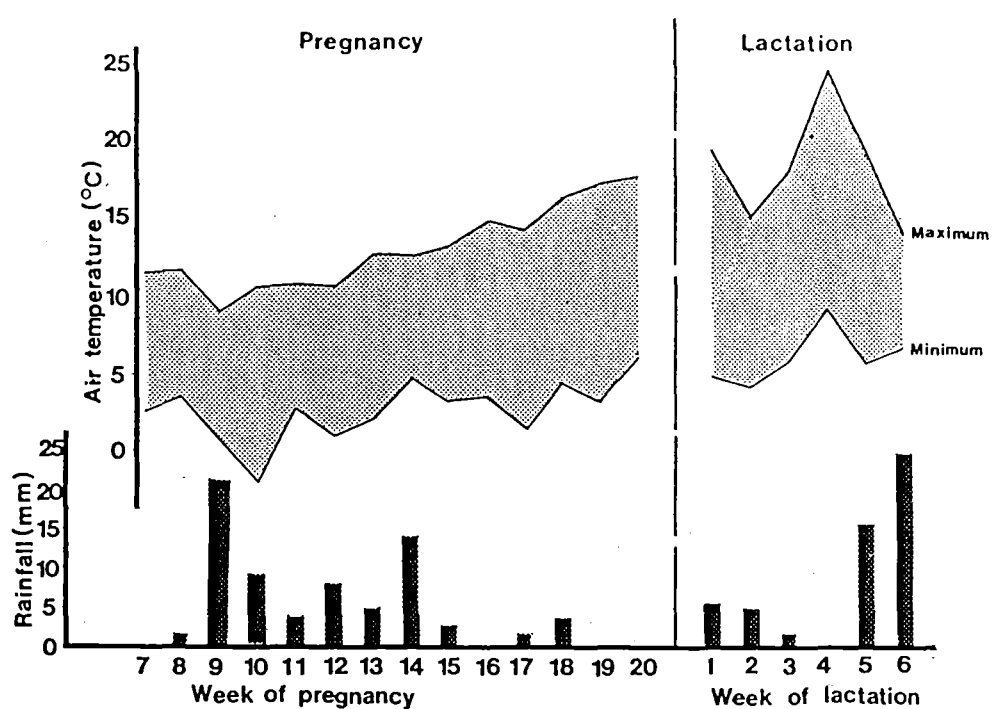
Figure 9.15:   Variation in daily air temperatures and
total rainfall during pregnancy and
lactation (Expt. B).

Table 9.11 Mean values for herbage mass (kg DM/ha),
percentage botanical composition, crude
protein (N X 6.25), gross energy content
(MJ/kg DM) and digestibility of the sward
before grazing during pregnancy (n = 24)
and lactation (n = 16) (Expt.B)

	Pregnancy			Lactation	
	L-	H-	SD		SD
Herbage mass	1260	2570	713.1	2410	499.2
Botanical composition -					
grass	51	66	12.0	57	11.7
clover	11	11	6.3	17	11.2
green material	62	77	18.3	74	22.9
dead material	36	20	12.1	25	3.9
Digestibility -					
DMD	.63	.70	.064	.74	.058
OMD	.68	.75	.054	.77	.054
Crude protein+	183	183		166	
Gross energy+	15.9	16.7		16.6	

+ estimated on 30% of samples
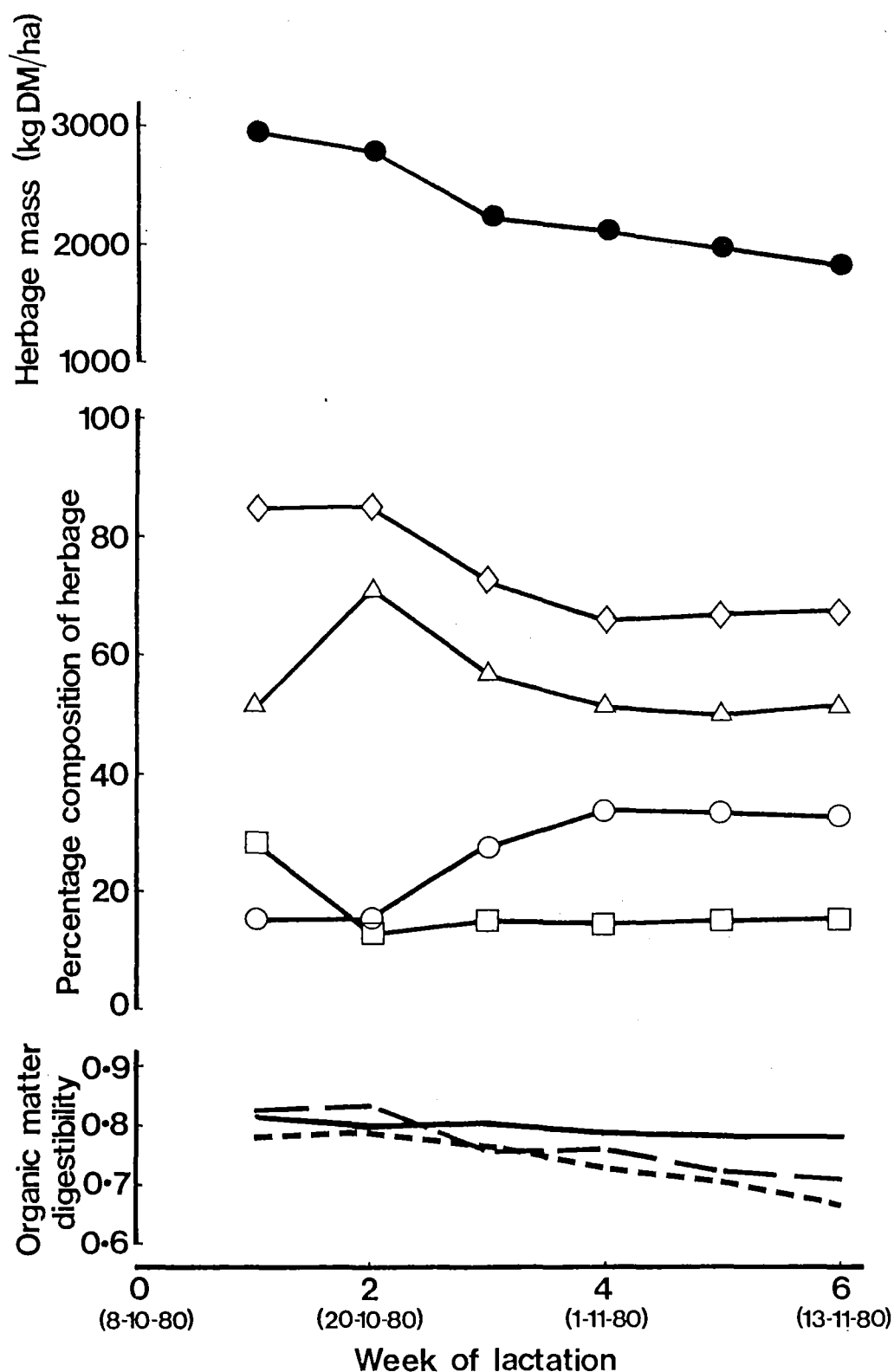
Figure 9.16: Mean values during lactation for pre-
              grazing herbage mass, ●——● ;
              botanical composition of herbage (green
              material, ◇——◇ ; grass, △——△ ;
              clover, □——□ ; dead material,
              ○——○) and digestibility (OMD) of
              herbage pre-grazing, ——; post-grazing
              ----; and of extrusa, ——   (Expt. B).

Table 9.12   Grazing intensity (no. ewes/ha), herbage allowance (kg DM/ewe/d), post-grazing herbage mass (kg DM/ha) and apparent dry matter intake (kg DM/ewe/d) for groups during pregnancy and lactation (Expt.B)

Herbage allowance group	Pregnancy L-		H-		SD	Lactation -L	-M	-H	-M(m)	SD
Grazing intensity	525		396			389	162	100	160	
Stage of pregnancy	mid+	late*	mid+	late*						
Number of observations	19	7	17	8						
Herbage allowance	0.55	1.02	1.82	2.08	0.245	2.20	5.10	8.40	5.30	0.871
Post grazing herbage mass	423	750	942	1400	281.9	910	1630	2040	1900	614.0
Apparent intake of DM	0.29	0.61	1.06	1.08	0.239	1.32	1.63	1.43	1.19	0.916

+ - weeks 6-16 of pregnancy; * - weeks 17-21 pregnancy

intake during lactation in groups of ewes rearing lambs though the mean value was 23% greater than that for machine-milked ewes.

9.18 Diet quality, individual feed intake during lactation, milk production and lamb live weight.

9.18.1 Nutritive value of diets. Mean D of extrusa showed little change during lactation (Fig. 9.16) compared with declining values for the sward before grazing. Values in -M and -H groups (Table 9.13) were similar and .05 lower in the -L group. The ME content of diets selected by -M and -H groups tended, as a consequence, to be greater than in the -L group.

9.18.2 Correction factors for Cr_2O_3 concentration in faeces. The average recovery of Cr_2O_3 in total faecal collections was 91 ± 1.3 percent with no difference among intake periods or herbage allowance groups. Losses of Cr_2O_3 from the animal were unlikely (discussed later) but use of a different grinding mill than in Expt.A may have resulted in greater losses of dust, and thus Cr_2O_3 during milling (Kotb and Luckey, 1972). Values for all samples were therefore arbitrarily increased by 7.7% to equate with the 98% percent recovery in the previous experiment. Trends in adjusted Cr_2O_3 concentrations in total faecal collections and in grab-samples (Fig. 9.17), were generally similar; there were no differences in mean concentration of Cr_2O_3 between samples of total collections and grab-samples or interactions between treatments and time.

Table 9.13   Mean values for digestibility, gross energy
             (MJ/kg DM) and metabolizable energy content
             (M/D, MJ ME/kg DM) of diets selected in
             allowance groups during lactation (n = 12
             (Expt.B)

	Lactation allowance				
	-L	-M	-H	-Mm	SD
Digestibility -					
DMD	.74	.79	.79	.80	.019
OMD	.77	.81	.81	.81	.021
Gross energy of					
extrusa+	16.5	17.2	17.5	17.3	
M/D of diet	10.2	10.9	10.8	11.2	

+ estimated on 30% of samples
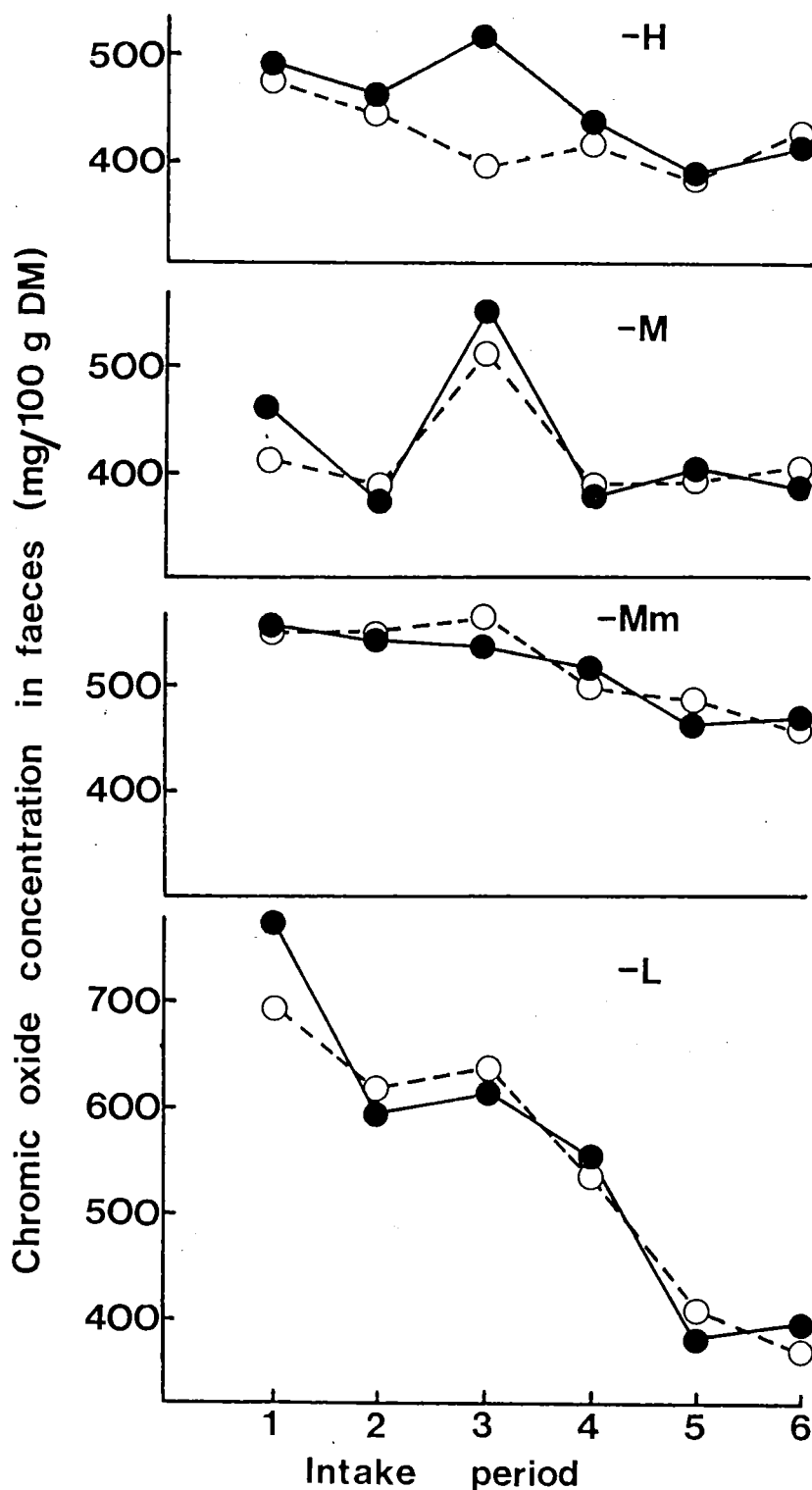
Figure 9.17: Chromic oxide concentration in faeces
              from total collections, ●——● and
              grab-samples, O---O   taken from ewes
              bagged for total collection (Expt. B).

9.18.3 <u>Feed intake.</u> Mean daily OMI during each 6 day period is given in Fig. 9.18. Ewes rearing lambs on -M and -H allowances had maximum OMI during week 2 of lactation (i.e. period 1) and those in the -L group during weeks 1-3. Machine-milked ewes showed little variation between periods. Comparisons of linear trends with time indicated that -M and -H groups showed greater (P<0.01) rates of decline in intake between periods compared with -L and machine-milked groups which showed no change. There was a significant difference in quadratic trends (P<0.05) between -M and -H compared with -L and -Mm groups.

Mean values for OMI and MEI during lactation are given in Table 9.14. There were no significant treatment interactions.

Ewes rearing lambs in -M and -H groups had, respectively, 45% and 65% greater intake than the -L group. OMI of machine-milked ewes was 12% lower than that of ewes rearing lambs on a similar allowance. Comparisons between groups on a per kg $W^{.75}$ basis gave differences generally of a similar order, but intakes of L- ewes were significantly greater (18%) than those of H- ewes.

The mean daily intake of grain offered to machine-milked ewes was 28 g/ewe and this contributed about 2% (0.392 MJ ME/d) to daily ME intake.

9.18.4 <u>Milk production.</u> Mean daily milk production, estimated by the oxytocin (O1 and O2) lamb suckling and weighing (S1 and S2) techniques alone and combinations of the two (T1 and T2) (see p 56), are given in Table 9.15.
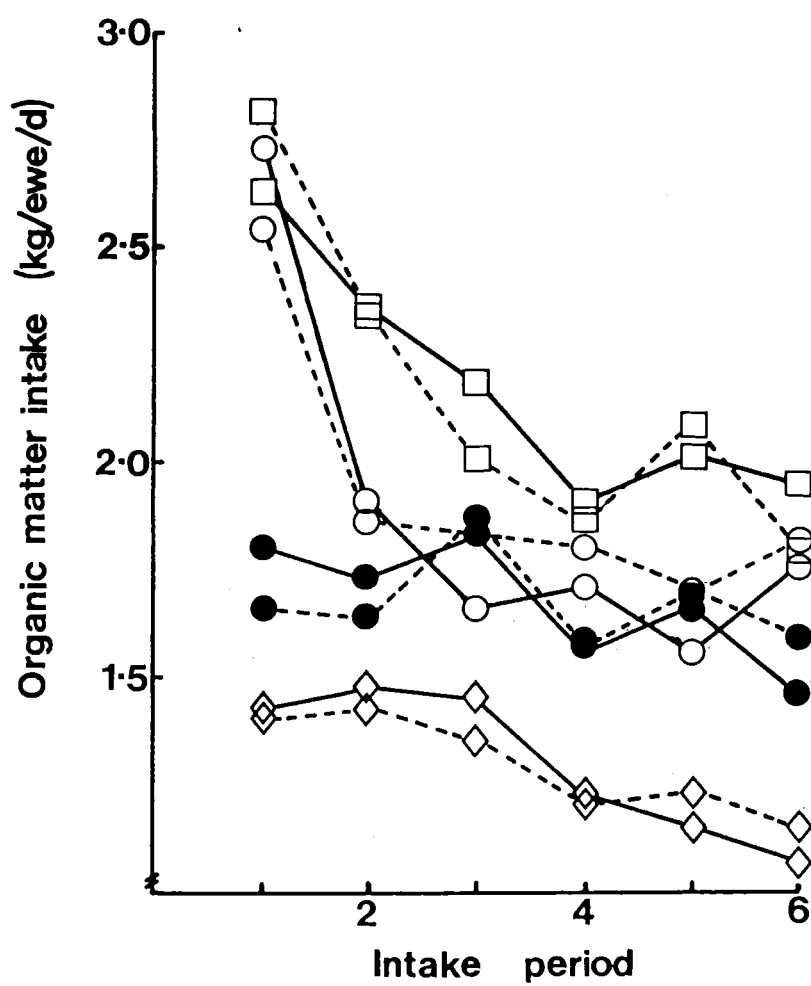
Figure 9.18:   Mean daily OM intake during lactation in

LL, ◇---◇   ;   HL, ◇——◇   ;   LM, ○--○   ;

HM, ○——○   ;   LMm, ●--●   ;   HMm, ●——●   ;

LH, □---□   ;   and HH, □——□   treatment

groups (Expt. B).

Table 9.14 Effects of herbage allowance during pregnancy and lactation on daily intake of organic matter (OM), digestible organic matter (DOM) and metabolizable energy (ME) during the first 6 weeks of lactation (Expt.B)

	Pregnancy allowance		Lactation allowance			Individual treatments							Significance tests			Machine-milked				Signif.
													Preg-nancy eff.	Lact-ation eff.	Inter-action					
	L-	H-	-L	-M	-H	LL	HL	LM	HM	LH	HH	SD				-Mm	LMm	HMm	SD	
Number of ewes	40	39	19	20	19	10	9	10	10	9	10					21	11	10		
OM intake-																				
kg/ewe	1.78	1.80	1.31	1.90	2.16	1.29	1.32	1.91	1.90	2.14	2.17	.266	NS	**	NS	1.67	1.67	1.68	.236	NS
DOM intake-																				
g/kg W	75	64	51	75	83	55	47	81	69	89	77	8.5	**	**	NS	65	69	60	7.8	*
ME intake-																				
MJ/ewe	22.9	22.8	17.3	23.4	27.7	17.4	17.2	23.5	23.3	27.6	27.9	3.25	NS	**	NS	21.0	21.0	20.9	2.76	NS
kJ/kg W	1200	1011	871	1133	1311	957	785	1227	1039	1416	1207	129.5	**	**	NS	1004	1079	922	111.2	**

Table 9.15 Mean daily milk production estimated by the oxytocin
(O), lamb suckling and weighing (S) techniques and
combinations of the two (T) (Expt.B)

| Tech-nique | Method | Allowance | | | mean | SD | Significance tests | | |
		-L	-M	-H			Allow-ance	Method	Inter-action
O	1	1.96	3.09	2.82	2.64				
O	2	2.19	2.89	3.07	2.72	0.587	NS	NS	NS
mean		2.08	3.00	2.95					
S	1	1.96	1.70	1.95	1.86				
S	2	1.59	1.98	2.30	1.95	0.553	NS	NS	NS
mean		1.76	1.84	1.76					
T	1	1.97	2.43	2.44	2.28				
T	2	2.01	2.64	2.87	2.51	0.452	**	NS	NS
mean		1.99	2.54	2.66					

Estimates using method 2 were generally greater, though not significantly so, than for method 1. Owing to this and the lack of interactions with allowance groups, means of methods 1 and 2, for each technique, were plotted by allowance groups against time in Fig. 9.19. There were no apparent treatment X technique differences in trends with time.

Regression equations for relationships during the 6 week lactation period, between total lamb body weight gain (Y, kg) and total milk yield (X, kg), using the three methods of estimation, are given in Table 9.16.

Table 9.16   Regression equations relating lamb
             body weight gain between birth and six
             weeks (Y, kg) and total milk production
             (X, kg) during the same period estimated
             by sample milking (O), lamb suckling (S)
             and a combination of the two techniques (T)

Technique	Regression equation	RSD	r^2
O	Y = 0.084 X + 10.97	2.708	.47
S	Y = 0.093 X + 12.92	2.916	.38
T	Y = 0.126 X + 7.70	2.308	.61

On average, 19% more of the variation in lamb body weight gain was explained by variation in milk yield estimated by combination than by O or S techniques individually.

Owing to the lower error variance and closer association with lamb body weight gain, the combination of
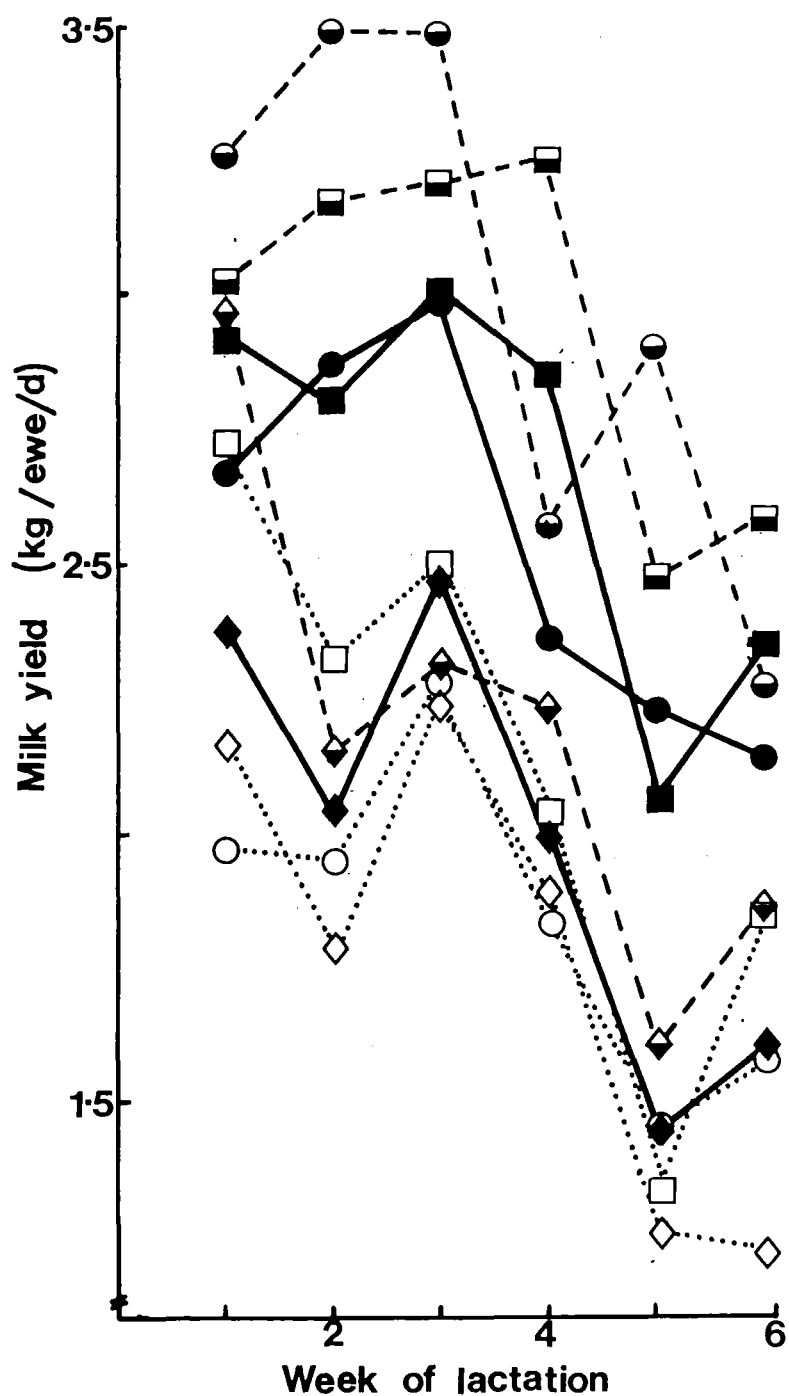
Figure 9.19:   Comparison of oxytocin,———— and lamb
               suckling, ········ techniques, and a combin-
               ation of the two, ——— ;   for estimation
               of mean daily milk production in -L, ◇ ;
               -M, ○ ;   and -H, □ groups (Expt. B).

techniques will thus be used throughout to estimate milk production of ewes rearing lambs.

Mean daily milk production each week (Fig. 9.20) for ewes rearing lambs was maximal during week 3 then subsequently declined to week 6, though LH, HL and HH groups showed a tendency to increase during week 6. There were no significant differences in trends with time between treatments. Machine-milked ewes showed comparatively less variation in mean yield with time. Maximum milk production occured during week 2 of lactation.

Mean daily milk production during the 6 week lactation period (Table 9.17) was 31% greater in -M and -H compared with the -L group. When expressed per kg $W^{.75}$, milk yield was 13% greater for L- compared with H- ewes. Mean milk yield per kg $W^{.75}$ in machine-milked ewes, estimated directly, was 32% lower than in ewes rearing lambs on the same allowance.

Changes in milk content of fat and total solids are given in Fig. 9.21. Similar patterns with time were observed in each allowance group. Fat content fluctuated from week to week, while total solids declined during the initial 1-2 weeks then generally increased with maximum values during week 6. There was little change with time in milk lactose or protein and no difference in trends with time among treatments for any milk components.

Treatment group means for milk composition and energy content (obtained from the relationship with total solid content derived in Expt.A), are given in Table 9.17. The content of protein, total solids and energy were greater in -L and -M compared with the H group. There
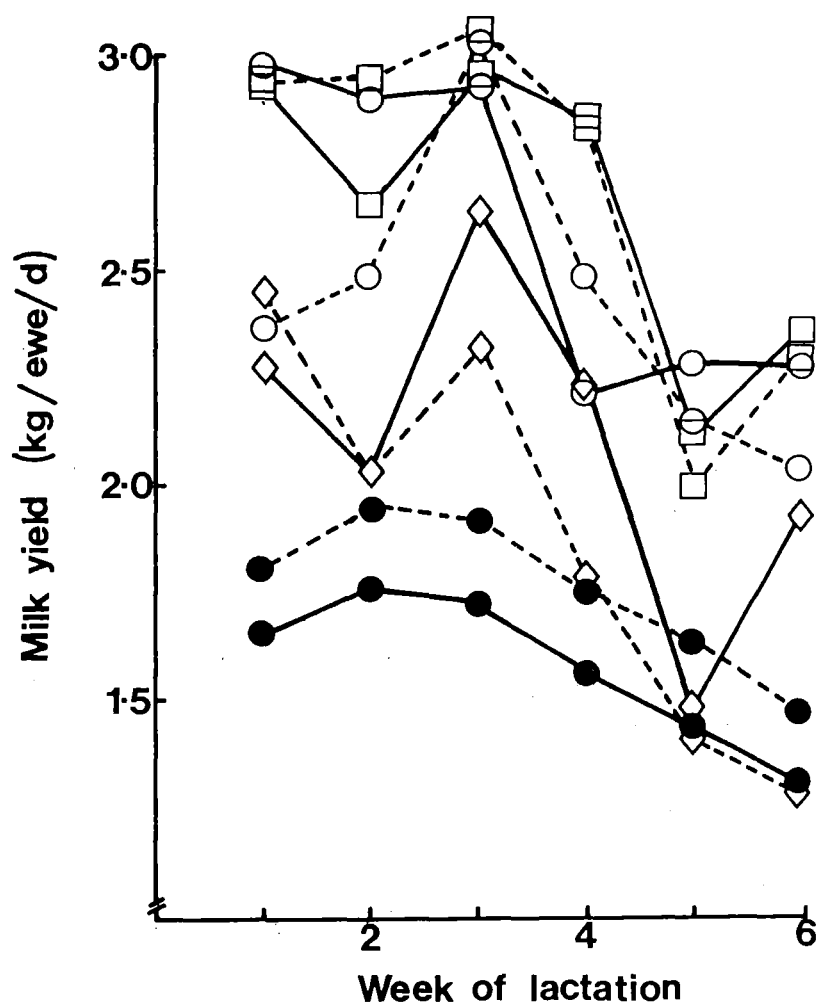
Figure 9.20:   Mean daily milk production in LL, ◇- - -◇ ;
               HL, ◇———◇ ; LM, ○- - -○ ; HM, ○———○ ;
               LMm, ●- - -● ; HMm, ●———● ; LH, □- - -□ ;
               and HH, □———□   treatment groups (Expt. B).

Table 9.17   Effects of herbage allowance during pregnancy and lactation on mean daily milk production, milk composition and energy content during during the first 6 weeks of lactation (Expt.B)

	Pregnancy allowance		Lactation allowance			Individual treatments						SD	Significance tests			Machine-milked			SD	Signif.
	L-	H-	-L	-M	-H	LL	HL	LM	HM	LH	HH		Preg-nancy eff.	Lact-ation eff.	Inter-action	-Mm	LMm	HMm		
Number of ewes	29	29	19	20	19	10	9	10	10	9	10					21	10	11		
Milk yield-																				
kg/ewe	2.35	2.45	1.99	2.54	2.66	1.88	2.10	2.49	2.59	2.68	2.65	0.247	NS	**	NS	1.67	1.75	1.58	.471	*
g/kg W$^{.75}$	123	109	100	123	126	103	97	130	115	136	116	14.6	**	**	NS	81	90	70	20.3	**
Milk composition (g/kg)																				
fat	77	76	79	78	71	80	79	81	76	69	74	16.4	NS	NS	NS	71	73	69	5.9	NS
protein (NX6.38)	40	39	40	40	39	41	39	41	39	39	39	4.5	NS	NS	NS	47	48	46	2.8	NS
lactose	50	50	51	52	48	51	52	51	53	49	47	10.5	NS	NS	N	48	48	49	13.9	NS
total solids	174	171	174	177	167	175	174	181	173	167	167	10.5	NS	**	NS	183	186	180	10.4	NS
Milk energy-																				
MJ/kg	4.7	4.6	4.7	4.7	4.5	4.7	4.6	4.8	4.6	4.5	4.5	.29	NS	*	NS	4.9	4.9	4.8	.29	NS
kJ/kg W$^{.75}$	568	501	470	578	553	482	462	625	530	597	510	98.7	**	**	NS	395	448	338	73.2	**
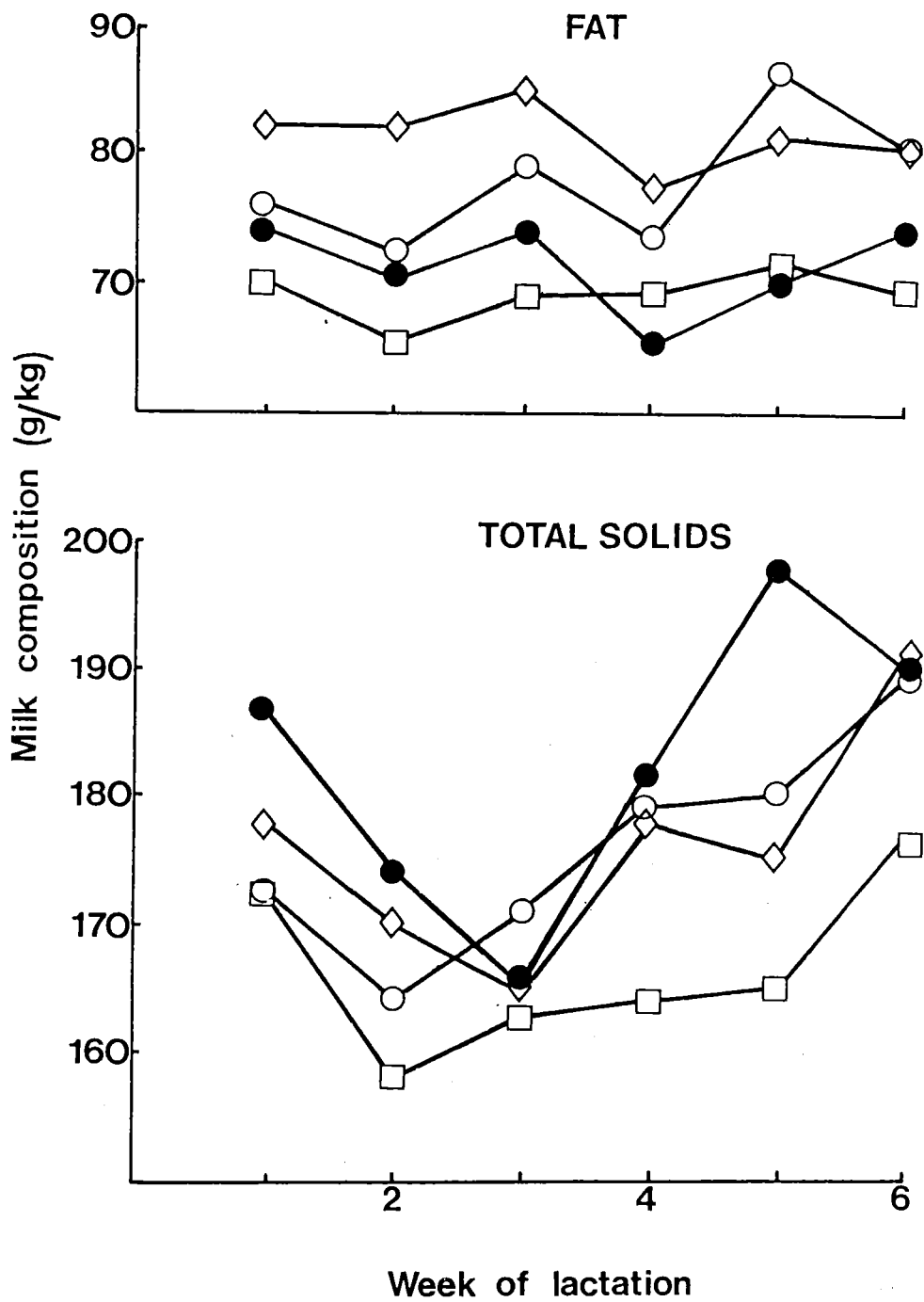
Figure 9.21:   Mean milk content of fat and total solids
for ewes in -L, ◇——◇ ; -M, ○——○ ;
-Mm, ●——● ; and -H, □——□   herbage
allowance groups (Expt. B).

was, however, a 20% greater milk energy production (per kg
$W^{.75}$) in -M and -H compared with the -L group and a 13%
greater production in L- compared with H- ewes.
Machine-milked ewes tended to have higher values for
protein, total solids and energy content, compared with
suckled ewes.

9.18.5 Lamb body weight. Relationships within
lactation allowance groups, between total lamb body weight
gain (Y, kg) and total milk production (X, kg), are shown
in the following regression equations -

	Group	Regression equation	RSD	r^2
(1)	-L (n=18)	Y = 0.143X + 5.67	1.933	0.50
(2)	-M (n=18)	Y = 0.118X + 8.77	2.533	0.54
(3)	-H (n=19)	Y = 0.093X + 11.87	2.400	0.42

The results indicate that between groups, 42-54% of
the variation in lamb gain was associated with variation
in milk production and that each kg of gain was associated
with the production of 7.0, 8.5 and 10.8 kg of milk
respectively in -L, -M and -H groups.

Mean body weight changes of lambs (Fig. 9.22) were
similar for all groups until week 4. The reduction in
growth rate of -L lambs during the final 2 weeks was
reflected in a significantly different quadratic trend
(P<0.05) compared with -M and -H groups. Linear trends
showed that lambs in -M and -H groups had, over the whole
period, greater average growth rates respectively by 46
and 60 g/d compared with those in the -L group. Mean
growth rate of lambs reared by H- compared with L- ewes
was on average 20 g/d greater.
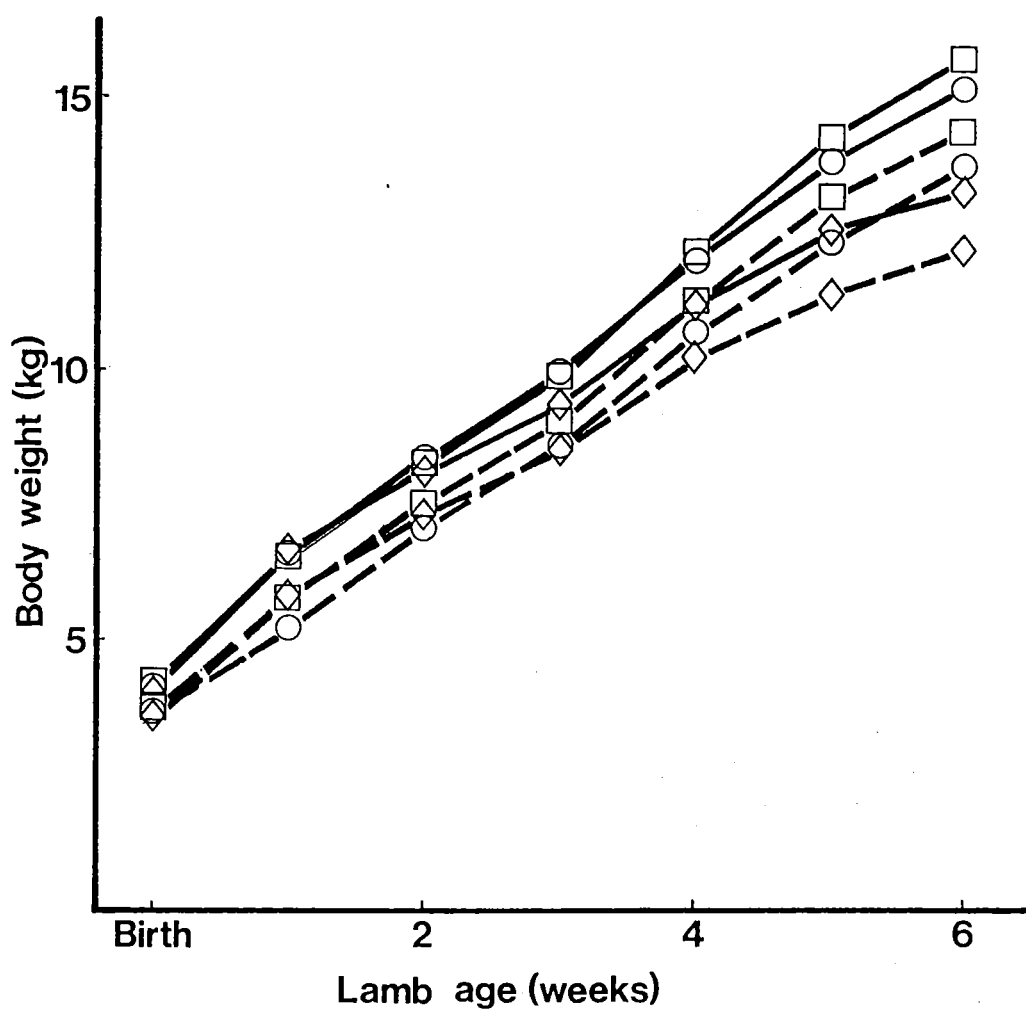
Figure 9.22:   Mean body weight changes of lambs in LL,

◇- - -◇ ;   HL, ◇———◇   ;   LM, O - - -O   ;

HM, O———O   ;   LH, □- - -□   ;   and HH,

□———□ treatment groups (Expt. B).

Mean lamb body weights during different stages of lactation, and growth rates, are given in Table 9.18.

9.19 Body weight and body composition of ewes.

9.19.1 Body weight. Low and high herbage allowances during pregnancy caused body weight differences between groups, immediately before and after parturition, of 18.4 and 15.7 kg, respectively, (Fig. 9.23). During lactation mean body weights of all treatment groups declined, except for increases during weeks 2 and 5.

Mean ewe body weights during weeks 2, 4 and 6 of lactation are given in Table 9.19. There were no significant interactions.

9.19.2 Weights of body parts. Mean weights of body parts in ewes slaughtered during early pregnancy, post-partum and after 6 weeks of lactation are given in Table 9.20. There were no significant treatment interactions.

Weight of reticulo-rumen showed a decrease of 17% and an increase of 5%, respectively in L- and H- ewes during pregnancy. At the end of lactation weights were 18% greater in -H and -M compared with the -L group. During pregnancy the complete alimentary tract increased in weight by 11% in H- ewes. Changes in weight of the alimentary tract during lactation were small and in final slaughter groups weights were 11% and 14% greater, respectively, for -M and -H compared with the -L group. Weight of contents (after fasting) of the alimentary tract

Table 9.18   Effects of herbage allowance during pregnancy and lactation on total body
weight of twin lambs (kg) during the first 6 weeks of lactation (Expt.B)

| | Pregnancy allowance | | Lactation allowance | | | | Significance tests | |
| | | | | | | | Pregnancy | Lactation |
	L-	H-	-L	-M	-H	SD	effects	effects
Number of observations	29	29	19	20	19			
birth	7.4	8.2	7.6	7.7	8.0	1.05	**	NS
week 2	14.5	16.6	15.3	15.5	15.8	1.92	**	NS
week 4	21.3	23.6	21.2	22.7	23.4	2.75	**	*
week 6	26.7	29.6	25.3	29.0	30.2	3.21	**	**
Gain/lamb from birth to 6 weeks(g/d)+	232	254	209	254	268	50.12	*	**

+ estimated by linear regression
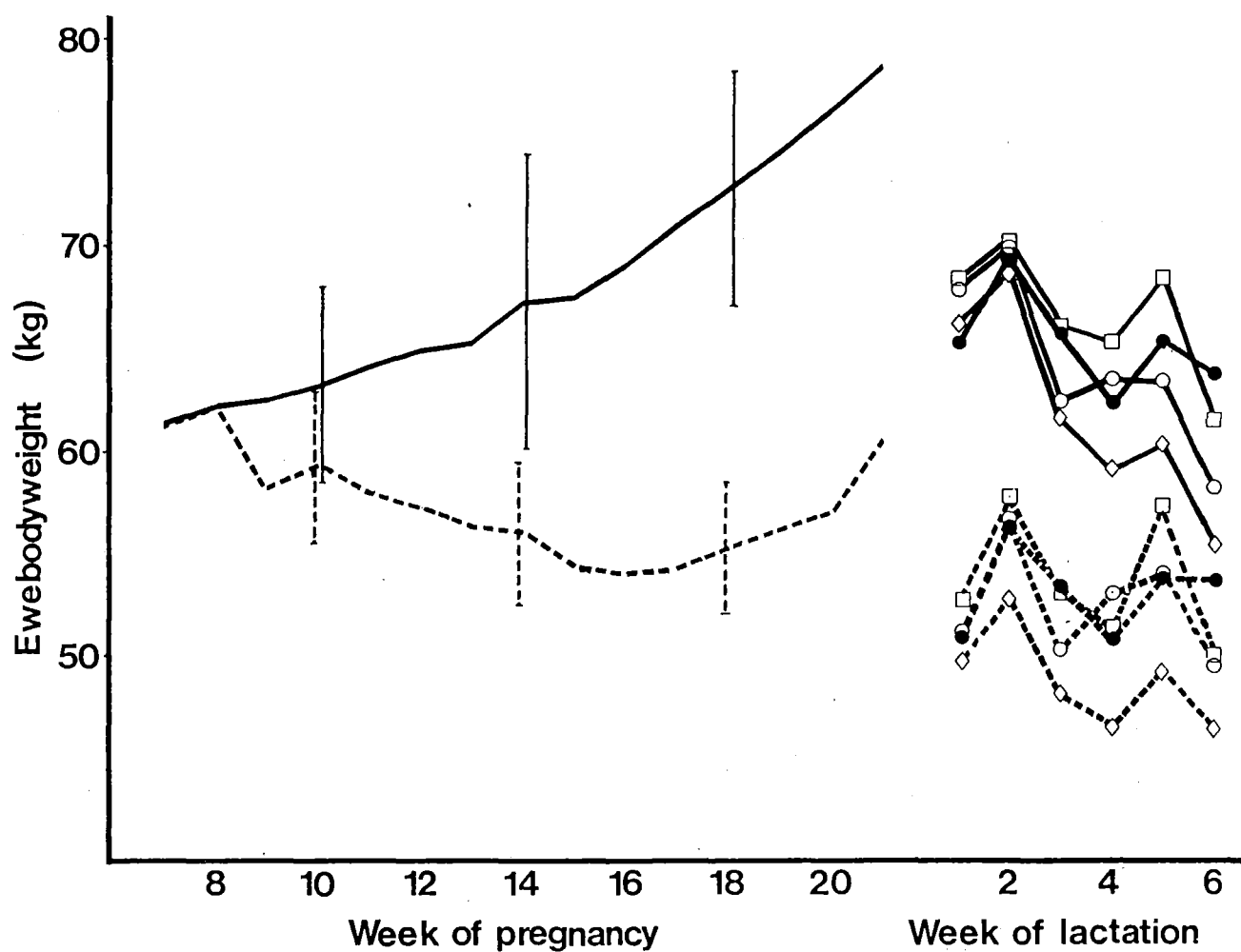
Figure 9.23:   Mean body weights of ewes during pregnancy

in L-, ---- ;   and H-, ——— groups (I - SD)

and during lactation in LL, ◇----◇ ; HL,

◇———◇ ; LM, O---O ; HM, O———O ;

LMm, ●---● ; HMm, ●———● ; LH, □---□ ;

and HH □———□   groups (Expt. B).

Table 9.19 Effect of herbage allowance during pregnancy and lactation on body weight (kg) of ewes during the first 6 weeks of lactation (Expt.B)

	Pregnancy allowance		Lactation allowance					Significance tests	
								pregnancy	Lactation
	L-	H-	-L	-M	-H	-Mm	SD	effects	effects
Number of animals	40	39	19	20	19	21			
post-partum	49.9	65.6	59.2	56.8	57.2	57.7	8.63	**	NS
week 2	55.8	69.6	60.6	63.2	63.9	62.7	9.44	**	NS
week 4	50.4	62.7	52.7	58.2	58.3	56.6	8.34	**	NS
week 6	46.9	56.9	48.0	50.5	52.5	55.9	7.48	**	**
mean body weight+	51.9	64.4	55.3	57.9	60.1	59.1	8.32	**	NS

+ means do not include post-partum weight

Table 9.20 Effects of herbage allowance during pregnancy and lactation on weights of body components of ewes (kg) immediately post-partum, after 6 weeks of lactation and of controls slaughtered in early pregnancy (Expt.B)

When slaughtered	Early pregnancy		Post-partum			Week 6 of lactation							Significance tests	
Main effects			Pregnancy allowance			Pregnancy allowance		Lactation allowance					Pregnancy	Lactation
Slaughter group	ISG		L-	H-		L-	H-	-L	-M	-H	-Mm		effects	effects
Number of ewes	10	SD	10	10	SD Signif.	39	40	19	20	19	21	SD		
Pre-slaughter body weight	61.9	6.14	48.3	62.6	8.98 **	45.1	54.7	45.9	48.5	50.3	54.0	7.41	**	**
Empty body	56.5	5.40	43.4	58.4	8.76 **	38.4	48.3	39.0	42.0	44.0	47.7	6.84	**	**
Reticulo-rumen	1.22	0.211	1.01	1.28	0.191 **	1.24	1.35	1.14	1.35	1.36	1.33	0.246	**	**
Alimentary tract	2.68	0.447	2.65	2.97	0.494 NS	2.66	2.83	2.47	2.73	2.82	2.92	0.466	*	**
Alimentary tract contents	5.37	1.960	4.83	4.17	1.025 *	6.69	6.34	6.85	6.60	6.33	6.32	1.300	NS	NS
Liver	0.913	.124	0.825	1.113	.135 **	0.947	1.071	0.881	1.038	1.152	0.963	.120	**	**
Kidneys	0.166	.027	0.153	0.181	.020 **	0.170	0.169	0.152	0.163	0.204	0.160	.058	NS	**
Udder	0.31	0.070	1.32	1.68	0.451 *	1.09	1.25	1.18	1.34	1.37	1.01	0.300	**	**
Greasy fleece	+		1.70	2.33	0.570 **	1.80	2.24	2.08	1.96	2.16	1.89	0.401	**	NS
Lamb litter at birth			4.27	5.98	1.883 **	5.89	6.95	6.78	5.71	6.58	6.64	1.800	**	NS

+ weight unavailable

showed an average reduction during pregnancy of 16% then an average increase of 45% by week 6 of lactation.

Liver weight increased by 22% during pregnancy in H- ewes and increased slightly during lactation. By week 6 of lactation the livers of -M and -H groups were, respectively, 18% and 31% heavier than those of the -L group. During pregnancy kidney weight showed reductions of 8-9% in both groups. At week 6 of lactation total kidney weight was 34% greater in the -H compared with the -L group.

Weight of dissected udder increased four-fold and five-fold, respectively, in L- and H- ewes during pregnancy and on average regressed by 22% during lactation. At the end of lactation udder weights were about 25% greater in -M and -H compared with the -L group. Machine-milked ewes had a similar final udder weight to the -L group.

Greasy fleece weight was 37% greater at the end of pregnancy in H- compared with L- ewes and showed no apparent change during lactation.

Mean total lamb birth weight in post-partum slaughter groups was 40% greater in H- compared with L- ewes but the corresponding difference for the remainder of ewes lambing was 18%. Average litter sizes for all ewes lambing were, respectively, 1.58 and 1.69 ± .538 for L- and H- groups.

9.19.3 Chemical composition and energy content. Mean weights of gross chemical components and body energy content during early pregnancy, post-partum and after 6

weeks of lactation are given in Table 9.21. There were no significant treatment interactions.

During pregnancy L- ewes lost 45% (85 g/d) of body fat. Losses of fat remaining post-partum, during lactation, were on average 52% (207 g/d) and 39% (152 g/d), respectively, for H- and L- ewes. Reductions in fat weight during pregnancy and lactation were proportionately greater from internal depots than from the carcass. Ratios of internal:total body fat indicated that internal fat comprised, respectively, 21%, 16% and 13% of total fat during early pregnancy, post-partum and at the end of lactation.

During pregnancy body water content decreased by 9% and 10%, respectively, in L- and H- ewes but there was little change during lactation. There was a 22% decrease in the mean weight of body protein in the L- group during pregnancy and a further loss of 6% in surviving ewes from this treatment during lactation. By comparison, H- ewes showed no change in protein content during pregnancy but lost 10% during lactation. At the end of lactation, H- ewes had respectively 10% and 20% greater weights of body water and protein than L- ewes.

Concentrations of components in the FFEB of ewes are also given in Table 9.21. At the end of lactation L- ewes had greater water concentration but lower protein compared with H- ewes. Consequently water:protein ratio was greater in L- compared with H- ewes by week 6 of lactation.

Total body energy content, estimated from the relationship derived in Expt.A (p 85), was 63% greater post-partum in H- compared with L- ewes and this

Table 9.21 Effects of herbage allowance during pregnancy and lactation on gross chemical composition and energy content of the bodies of ewes immediately <u>post-partum</u>, after 6 weeks of lactation and of controls slaughtered in early pregnancy (Expt.B)

When slaughtered	Early pregnancy		Post-partum				Week six of lactation								
Main effects			Pregnancy allowance				Pregnancy allowance		Lactation allowance					Significance tests	
														Pregnancy	Lactation
Slaughter group	ISG	SD	L-	H-	SD	Signif.	L-	H-	-L	-M	-H	-Mm	SD	effects	effects
Fat weights (kg)															
kidney+	1.72	0.798	0.58	1.13	0.441	*	0.19	0.59	0.29	0.29	0.39	0.55	0.299	**	*
omental+	2.43	0.755	1.10	2.04	0.702	**	0.40	1.20	0.54	0.70	0.88	1.04	0.517	**	*
carcass++	14.89	2.846	8.79	15.03	4.113	**	4.41	9.33	5.11	5.97	7.02	9.05	3.048	**	**
total++	19.00	3.990	10.50	18.20	5.090	**	5.00	11.11	5.93	6.96	8.29	10.64	3.704	**	**
Weights of components (kg)															
water	27.61	2.724	25.12	30.48	3.451	**	25.90	28.42	25.60	26.93	27.36	28.54	2.928	**	**
protein	7.94	1.260	6.22	7.82	0.963	**	5.87	7.00	5.88	6.37	6.58	6.85	0.860	**	**
ash	1.92	0.203	1.60	1.90	0.160	**	1.60	1.78	1.63	1.68	1.76	1.69	0.245	**	NS
Ratios of components															
internal/total fat	.213	.0550	.155	.170	.0399	*	.112	.152	.145	.125	.125	.132	.048	**	NS
water/FFEB	.737	.0188	.762	.758	.0084	NS	.777	.764	.774	.770	.767	.770	.0108	**	NS
protein/FFEB	.211	.0183	.189	.194	.0079	NS	.176	.188	.177	.181	.184	.184	.0073	**	*
ash/FFEB	.052	.0045	.049	.048	.0035	NS	.048	.048	.049	.048	.049	.046	.0044	NS	*
water/protein	3.51	0.356	4.04	3.91	.2070	NS	4.45	4.07	4.43	4.27	4.18	4.19	.285	**	*
Body energy															
MJ/kg EBW	16.10	2.093	12.43	14.82	2.257	*	7.87	11.78	8.57	9.20	9.90	11.38	2.293	**	**
total (MJ)	914	166.2	543	888	222.1	**	316	583	355	403	461	563	162.4	**	**

+ weight of dissected fat

++ weight of chemically determined fat

difference had increased by week 6 of lactation to 84%. At the end of lactation machine-milked ewes had 59%, 40% and 22% greater body energy content, respectively, than -L, -M and -H groups.

9.19.4 <u>Body composition of live ewes.</u> The regression relationship between pre-slaughter fasted (unshorn) body weight (X, kg) and empty body weight (Y, kg), for ewes slaughtered <u>post-partum</u> (n=20), did not differ between L- and H- groups and was -

$$Y = 1.013 \ X - 5.268 \quad RSD = 1.064 \ r^2 = 0.99$$

The closeness of this relationship enabled direct prediction of body fat content (Y, kg) in live ewes <u>post-partum</u> from fasted body weight (X, kg). The relationship did not vary between L- and H- groups, and the following regression equation was used -

$$Y = 0.519 \ X - 14.42 \quad RSD = 2.335 \ r^2 = 0.87$$

Similarly, prediction of body protein (Y, kg) was obtained from fasted body weight (X, kg) using the following regression equation obtained from ewes slaughtered <u>post-partum</u> -

$$Y = 0.105 + 1.19 \quad RSD = 0.333 \ r^2 = 0.90$$

Changes in weights of body protein and fat, between early pregnancy, <u>post-partum</u> (predicted values) and the end of lactation, are shown in Fig. 9.24. Ewes in the L-
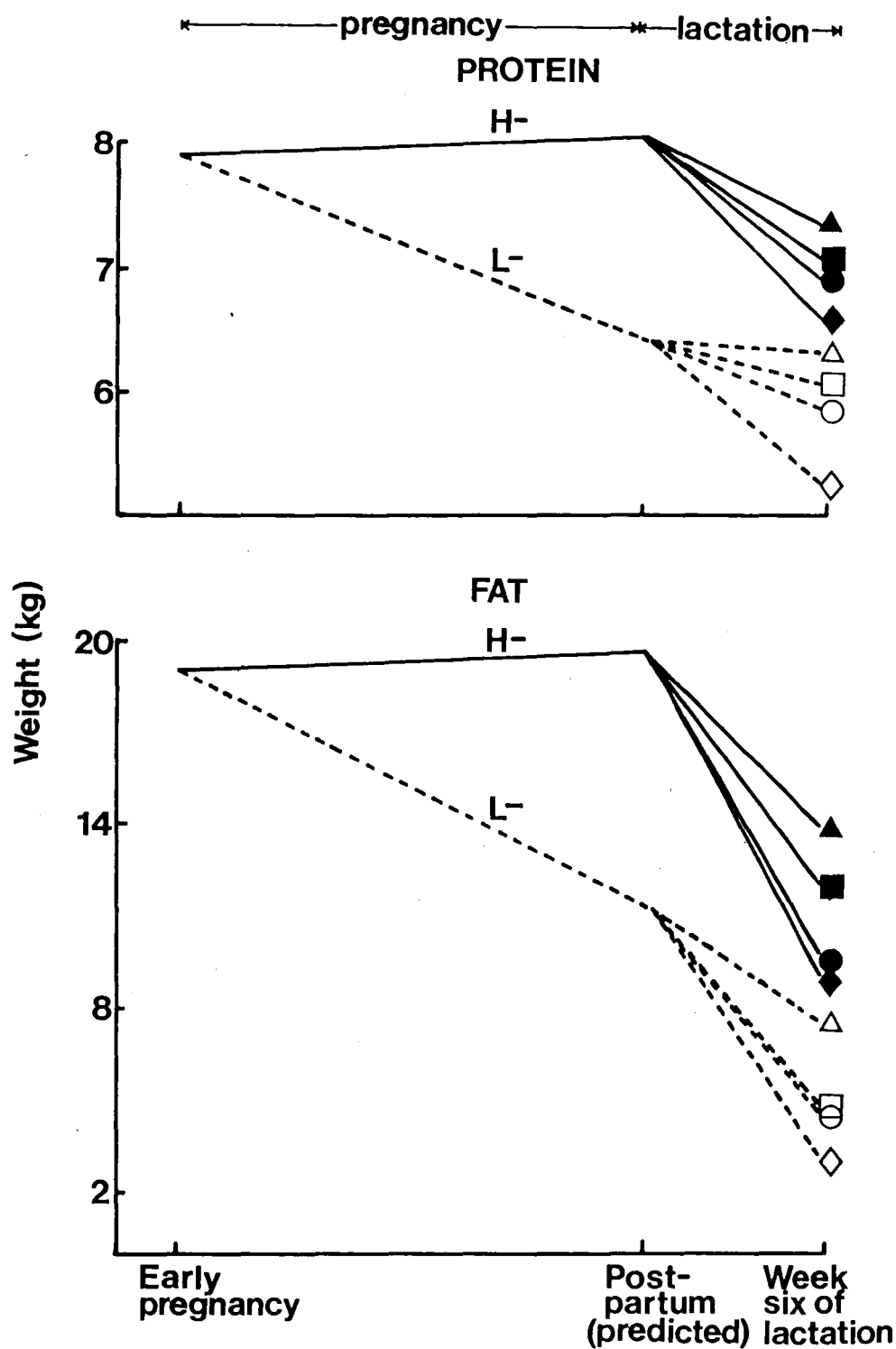
Figure 9.24: Predicted weights of body protein and fat in L- and H- groups post-partum and actual weights in LL, ◇ ; HL, ◆ ; LM, ○ ; HM, ● ; LMm, △ ; HMm, ▲ ; LH, □ ; and HH ■ groups slaughtered at week 6 of lactation (Expt. B).

group lost 15 g/d body protein during pregnancy. During lactation negative protein balances ranged from 7 (LH) to 43 g/d (HL) and losses of body fat ranged from 157 (LH) to 287 g/d (HL).

9.20 Utilization of energy during lactation.

9.20.1 Partitioning of energy. During the 6 week lactation period the partitioning of ME consumed (MEI, MJ/d) between body maintenance requirement (MEBW, MJ ME/kg $W^{.75}$/d) and milk energy output (MKE, MJ/d), and the contribution of mobilized tissue energy (TSE, MJ/d) to milk synthesis, is shown in the following regression equations for L- (n=29) and H- (n=29) ewes rearing lambs, and those machine-milked (n=21, L- and H- combined).

Suckled (L-) MEI = 0.719 MEBW + 1.45 MKE - 0.585 TSE
        (SE)   (.2156)   (.2812)   (.1939)
            RSD = 3.084 r^2 = 0.59

Suckled (H-) MEI = 0.676 MEBW + 1.56 MKE - 0.781 TSE
        (SE)   (.1117)   (.1966)   (.1382)
            RSD = 2.571 r^2 = 0.78

Machine-
milked   MEI = 0.688 MEBW + 1.18 MKE - 0.318 TSE
(L- and H-) (SE)   (.1125)   (.2346)   (.1779)
            RSD =2.091 r^2 = 0.40

Correlation coefficients between independant variables in the above regressions are set out in Table 9.22. There were significant positive correlations between MEBW and both TSE ($P < 0.05$) and MKE ($P < 0.01$) in the L- group and a negative correlation between TSE and MKE in the H- group.

Estimates of maintenance requirement (i.e. bMEBW), efficiency of utilization of ME above maintenance for milk synthesis, K_1 (i.e. 1/bMKE) and efficiency of utilization of tissue energy for milk production (i.e. bTSE/bMKE), derived from these equations, are given in Table 9.23.

There was little variation between L- and H- ewes in maintenance requirement and K_1 values but utilization of body energy reserves appeared to be 25% more efficient in H- compared with L- ewes. Machine-milked ewes showed similar average maintenance requirement to suckled ewes but had a considerably higher K_1 value and lower efficiency of body tissue energy utilization.

Table 9.22 Correlation coefficients between independant
variables in energy partitioning regressions
(Expt. B).

| | Pregnancy allowance group | | | | Machine-milked group | |
| | L- | | H- | | L- and H- | |
Independant variables	TSE	MKE	TSE	MKE	TSE	MKE
MEBW	.47	.49	-.34	.31	-.33	-.26
MKE	.19		-.42		-.02	

Table 9.23 Estimates of maintenance requirement
(MJ ME/d), efficiency of conversion
of ME above maintenance to milk energy (K)
and efficiency of utilization of body tissue
energy for milk production by suckled ewes
offered low (L-) or high (H-) allowances during
pregnancy and for machine-milked ewes (Expt. B).

| | Maintenance requirement per kg | | | K_1 | Tissue energy utilization |
	MEBW	MBW	W		
Suckled (L-)	.719	.649	.245	.69	.40
Suckled (H-)	.676	.621	.232	.64	.50
Machine-milked (L- and H-)	.688	.609	.227	.85	.27

DISCUSSION

9.21 Feed intake during lactation.

9.21.1 Animal measurement. The accurate measurement of faecal output and feed digestibility are crucial for reliable estimation of feed intake in sheep grazing highly digestible swards.

The recovery of $98 \pm 1.9\%$ of Cr_2O_3 in bagged animals in Expt.A provided reassurance of accuracy of estimation of FO. The bias of 14% in estimating Cr_2O_3 concentration from grab sampling is disturbing but the consistency across groups and between periods allowed corrections to be made with confidence. The lower recovery of $91 \pm 1.3\%$ in Expt.B may have been due to regurgitation of capsules, incomplete collection of faeces or losses during sample preparation. Use of similar methods as in Expt.A and careful observation following dosing and in the paddock tended to rule out losses from the animal so I have assumed the latter applied and have corrected accordingly. Lack of bias with grab sampling in Expt.B compared with Expt.A, however, was surprising. A more erratic pattern of intake probably occurred in Expt.A as the ewes were taken off pasture for approximately 4 h each day during milking in contrast to only 30-40 min in Expt.B. Also in Expt.B the relatively low rainfall may have resulted in lower water intake (drinking water was not offered in either experiment). To suggest that this significantly influenced the fluid content of digesta, the fraction in which Cr_2O_3 is suspended (Raymond and Minson, 1955), and therefore movement of the marker, would be speculative. The mean DM content of faeces in Expt.B was, however, 262

g/kg compared with 206 g/kg in Expt.A.

Bias in estimates of D of extrusa owing to mastication and removal of plant OM with saliva, was unlikely. Observations with O/F ewes offered fresh cut herbage indoors (unpublished data) verified the correction factor of Langlands (1975) which was used.

Of some concern is the possibility that level of intake may have influenced in-vivo D values resulting in biased estimates of intake between treatments. Depression of D by up to .028 for each maintenance increment of feeding has been found with conserved forage-concentrate diets (Gardner and Hogue, 1966; Robertson and Van Soest, 1975). Information for fresh herbage diets consumed by sheep is lacking though Hutton (1963) showed a relatively small difference in D of .007 between non-lactating and lactating dairy cows even though intakes of the latter were 50% greater. Hutton's data suggest that the likely overestimation of D at the highest feeding levels in Expts.A and B, would have been no greater than .01. This would have resulted in an overestimate of intake in -M and -H groups of less than 2.6%. Any bias due to level of feeding would therefore appear to be small.

9.21.2 Diet selection. There was no difference in herbage selection between groups in Expt.A i.e. all O/F sheep selected herbage of .025 higher D value than that of the sward offered. In Expt.B, however, -M and -H groups selected material with D value .055 higher than that offered compared with .006 in the -L group. Reduced selectivity by -L ewes was associated with a lower residual herbage mass (910 kg DM/ha) compared with -M and -H groups (1630 and 2040 kg DM/ha, respectively). The

relatively greater selection by -M and -H groups in Expt.B was associated with more dead material in the sward (24%) than was present in Expt.A (13%).

Previous studies have shown greatest selectivity on poorer quality pastures (Langlands, 1975). Differences of between 0 and 2 percentage units in D have been observed on swards with a mean OMD of .76-.80 (Penning and Gibb, 1979; Milne et al., 1981). The present results suggest that the nutritive value of diets selected by lactating ewes may decrease at high grazing pressure, particularly when the sward contains more than 20% of dead material. Had O/F ewes not been used in Expt.B bias in estimates of intake of up to 25% would have occurred in -M and -H compared with the -L group. This emphasises the importance of using O/F sheep on relatively highly digestible but heterogeneous swards, particularly where different grazing intensities are being compared.

9.21.3 <u>Pattern of intake.</u> Organic matter intake during lactation in machine-milked ewes was similar in both experiments and varied little with time (Figs. 9.8 and 9.18); a maximum value of 2.2 kg OM/ewe/d was recorded during weeks 3-4. Ewes suckling lambs, particularly those in -M and -H groups, however, showed maximum intake of 2.5-2.8 kg OM/d during week 2 and then a declining trend to week 6.

Gibb and Treacher (1978) found that twin-rearing ewes offered a high allowance (116 g OM/kg W/d) and herbage mass (>4,000 kg OM/ha) had maximum intake of about 3.3 kg OM/d during the first 3 weeks of lactation. Later attainment of maximum intake (weeks 4-7) has been attributed to limitations imposed by low herbage mass

(<800 kg OM/ha) during early lactation (Maxwell et al.,1979; Gibb and Treacher, 1980).

Previous studies with conserved forage-concentrate diets have shown that maximum feed intake can lag 3-4 weeks behind peak milk production (Hadjipieris and Holmes, 1966). Physical bulk limitation in the alimentary tract during early lactation has been advanced as a causitive factor (Forbes, 1970). The present results, and other data with the grazing ewe suggest that maximum intake can be achieved during the initial weeks of lactation providing herbage mass is above 800-1000 kg DM/ha.

9.21.4 Regulation of intake. Important factors associated with level of intake are physical capacity of the alimentary tract (Forbes, 1970) and rate of passage of digesta (Ulyatt et al.,1976). At week 6 of lactation mean increases of 40-50% in weight of gut-contents after fasting, compared with those observed at the beginning, were associated with a decline in weight of the empty alimentary tract. This is in contrast with increased weight of alimentary tract during early lactation found by Fell et al (1972) and Cowan et al (1980a) with conserved forage-concentrate diets.

The increased weight of digesta in final slaughter groups may have been due to characteristics of the feed rather than increased gut-capacity. Greater fibre content and reduced D of herbage during the latter stages of lactation could have hindered the rate of particle breakdown in the reticulo-rumen and reduced the rate of passage of digesta (Ulyatt et al.,1976). The final weight of gut-contents (approximately 6.5 kg) was greater than the equivalent weight (4.5 kg) observed by Ulyatt and

Barton (1964) for lactating ewes on a fresh herbage diet. However, even with fasting losses (2.8 kg) added, this level of fill was still markedly lower than the range of 14-23 kg observed by Cowan et al (1980a) on roughage diets. The higher D and different chemical and physical composition of fresh herbage, would have been associated with a lower retention time of digesta compared with the 31-39 h reported by Cowan et al (1980a) at similar levels of feed intake and milk production. Calculation of mean retention times during week 6 of lactation, using a relationship similar to that of Ulyatt (1971) and weight of gut-contents with fasting losses added (assuming a DM content of 100 g/kg digesta), gave values of 18, 13, and 12 h respectively for -L, -M and -H groups in Expt.A and 21, 13, 12 and 14 h for -L, -M, -H and -Mm groups in Expt.B. Ulyatt (1971) reported retention times of 6-10 h with adult wether sheep grazing temperate pastures.

The comparatively lower retention times with fresh herbage diets in the present study, were associated with similar feed intakes as with conserved forage diets, at comparable levels of milk production (Cowan et al., 1980a). In addition, ewes in the present study, irrespective of level of milk production, were in negative energy balance. This suggests, in contrast to the hypothesis of Hodgson (1977), that intake on highly digestible swards is regulated metabolically, rather than by physical bulk or rate of passage, particularly at low levels of milk production. For example, if machine-milked ewes had achieved intakes similar to those of suckled ewes on the -H allowance, they would have theoretically been in positive energy balance i.e. assuming a K_1 value of .62, MEm of 12.5 MJ ME/d and milk

energy production of 8.5 MJ/d, ME intake above 26.2 MJ/d would have been required.

There was some evidence for regulation of intake according to level of body fatness. In both experiments the intake (g/kg $W^{.75}$) of ewes restricted during pregnancy (L-) was 14% greater than that of those well fed (H-). This may have been due to suppression of intake as a result of greater body fat content of H- compared with L- ewes (Forbes, 1969a; Baile and Forbes, 1974; Stern et al., 1978). The similar result with both machine-milked and suckled ewes (i.e. at different levels of milk production), suggests the effect of body fatness may have been metabolically-hormonally induced (Baile and Forbes, 1974) rather than through physical limitation (Forbes, 1969a).

9.21.5 Feed intake. The response of intake (kg OM/ewe/d) to increasing herbage allowance showed a diminishing curvilinear trend for both machine-milked and suckled ewes (Fig. 9.25). This suggests that both categories of ewe were approaching maximum intake at the highest allowance in contrast to a linear trend shown by Gibb and Treacher (1978) over similar allowances. The greater feed intake of suckled (-M and -H groups) compared with machine-milked ewes, must be attributable to a greater physiological drive induced by higher milk-production. The lower intake of suckled ewes compared with machine-milked ewes at the low allowance may have resulted from competition with lambs for available herbage. Slightly greater mean intake by machine-milked ewes in Expt.A compared with Expt.B may have reflected the more favourable sward qualities in the first year.
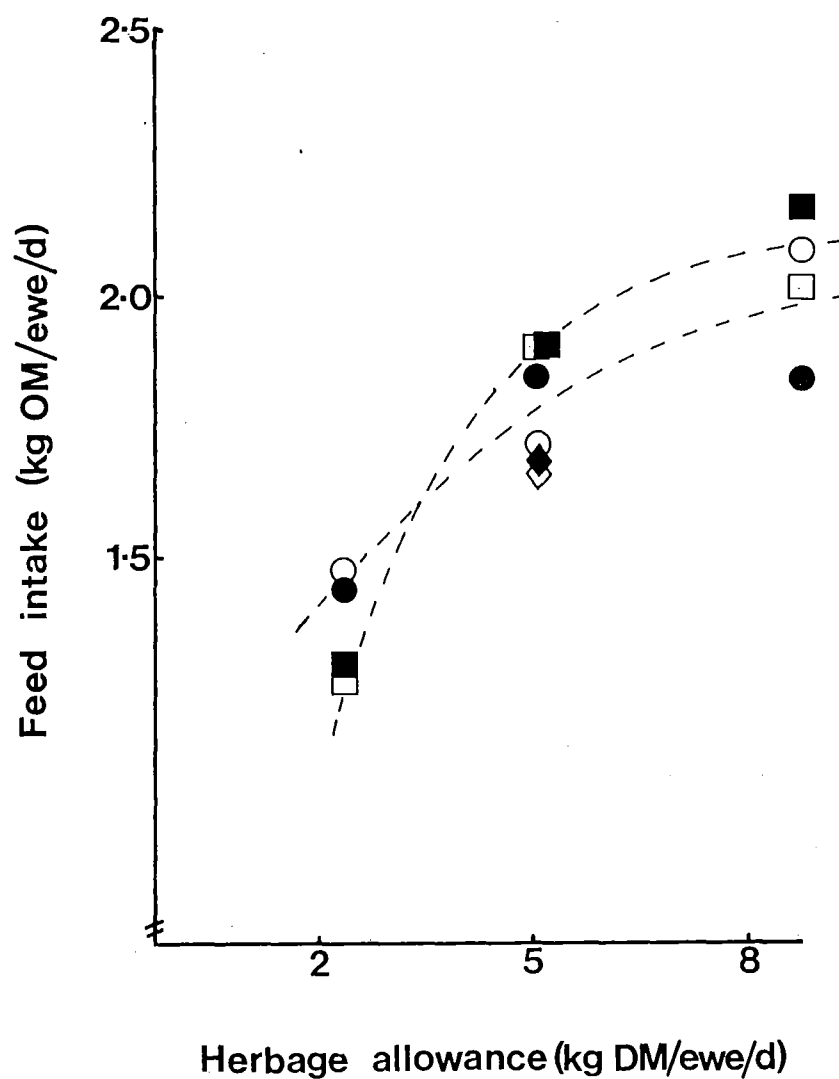
Figure 9.25:   Relationship between mean feed intake and
               herbage allowance for machine-milked groups
               in Expt. A (L-, O;   H-, ●) and Expt. B
               (L-, ◇;   H-, ◆) and suckled groups in
               Expt. B (L-, □;   H-, ■).

The range of intakes shown in the present experiments (51-83 g DOM/kg $W^{.75}$/d) can be compared with other studies with the grazing ewe in Table 4.2. Estimates (g DOM/kg $W^{.75}$/d) for ewes with twin lambs have included 75-96 (Coop and Drew, 1963), 36-73 (Gibb and Treacher, 1978), 85 (Maxwell et al.,1979) and 39-54 (Gibb and Treacher, 1980).

9.21.6 <u>Comparison</u> <u>of</u> <u>"animal"</u> <u>and</u> <u>"sward</u> <u>difference"</u> <u>measurements</u> <u>of</u> <u>intake.</u> Chromic oxide dilution was necessary in the present experiments to provide measurement of intake in individual ewes for estimates of energetic efficiency. Sward sampling was used primarily to quantify herbage on offer but measurements in Expt.A allowed comparison of intake with animal estimates on a group basis.

Assessment of herbage growth in Expt.A was made from two sequences of 6 estimates of herbage mass during days 3-21 and 22-39 of lactation. Linear regressions of herbage mass (Y, kg DM/ha) on time (X, days) gave respective b values of 90 (RSD= 17.8, r^2=.87) and 226 (RSD= 44.2, r^2=.87) indicating herbage growth of 90 and 226 kg DM/ha/d during the two periods respectively. These estimates are considerably greater than long term monthly means of around 40 kg DM/ha/d on lighter soils in this region (Rickard and Radcliffe, 1976). Hoglund and Brock (1978) proposed a "response surface method" for estimating herbage growth at any one time and J. H. Hoglund (pers. comm.) suggests that short term growth rates of the magnitude observed, have been recorded by this technique in the area.

Dry matter intakes of groups estimated by chromic oxide dilution and sward sampling are given in Table 9.24

Table 9.24   Comparison of herbage DM intake (kg DM/ewe/d) by ewes during lactation using "animal" and "sward difference" techniques (Expt.A)

	herbage allowance		
	-L	-M	-H
"Animal"	1.72	2.01	2.17
"Difference"+			
- uncorrected	1.23	1.20	1.44
- corrected	1.56	2.05	2.77

+ corrected for herbage growth

Compared with animal measurement, uncorrected "difference" estimates underestimated intake by 30-40%. Addition of herbage accumulation to pasture disappearance tended to equate results from the two techniques in -L and -M groups but gave a 28% overestimation in the -H group.

These differences are similar to the findings of Ulyatt et al (1974) showing that uncorrected "difference" methods can underestimate intake by up to 40%. The possibility of considerable bias, particularly with different grazing intensities and rapid herbage growth, suggests that animal methods are essential for accurate estimates of intake in groups of sheep. The major role for sward sampling is in estimates of allowance and residual herbage, and as an extension tool for interpretation of results between different studies.

9.22 Feed intake during pregnancy.

Results from sward sample measurements were probably underestimated owing to the unaccounted contribution of herbage growth, particularly during the final weeks of pregnancy. In addition, there was a possible source of bias with L- groups due to soil compaction with high stocking intensities, particularly in wet conditions. Sampling to "ground level" appeared to result in harvesting of plants at a lower level after- compared with prior to- grazing. If this was a real observation residual herbage mass would have been overestimated and intake underestimated in L- groups. This can not be quantified.

Due to the probable innaccuracy of intake estimates, nutritive status of ewes during pregnancy will be considered only in relation to lamb birth weight and maternal body energy balance, and at a later stage.

9.23 Milk production.

9.23.1 Measurement. Machine milking provided accurate estimates of milk production but utilization of twin suckling to stimulate higher levels of milk production made measurement more difficult. A high labour requirement and interference with ewe grazing precluded use of lamb suckling and weighing over a 24 h period on one day each week. Oxytocin-sample milking requires less labour and is quicker but can result in overestimation of milk yield. By compromise a combination of both techniques was adopted, and measurements restricted to two 4 h separation periods.

Lamb suckling alone gave much lower estimates of milk production than did use of oxytocin and machine-milking. It is difficult to judge whether the difference was a result of supernormal emptying at the milking prior to lamb suckling (McCance, 1959), the failure of lambs to withdraw all milk (Coombe et al.,1960), or a combination of the two. The comparatively low correlation of lamb suckling estimates of milk production with lamb growth (Table 9.16) and large variation (indicated by SE's) in quantities of residual milk following lamb suckling (106 ± 86.9, 148 ± 100.3, and 147 ± 120.1 in -L, -M and -H groups respectively for a 40 min interval) indicate that lamb suckling alone was less accurate than oxytocin or a combination of the two methods. The lack of a trend for change in the difference between techniques with time, within allowance groups (Fig. 9.19), suggests the possibility of incomplete suckling due to behavioural problems with ewes and/or lambs rather than a specific effect of lamb appetite.

Although several workers (McCance,1959; Denamur and Martinet, 1961; Morag, 1968; Thompson et al.,1973) have suggested that administration of oxytocin does not increase milk secretion rate in the short term, comparison of the two combinations of methods suggests there may have been an effect. Three oxytocin measurements with T2, compared with 2 for T1, resulted in greater combined estimates of milk production by 2%, 9% and 18% in -L, -M and -H groups, respectively, though these differences were not statistically significant (Table 9.15). The apparent stimulation of milk secretion by oxytocin may have been due in part to the relatively high dose used (10 IU), because of the intramuscular route of injection (Geenty,

1980), and to ensure complete removal of milk (McCance, 1959). No bias in means among groups would have occurred however, as half of the ewes in each group were subjected to each combination of techniques.

9.23.2 <u>Milk yield.</u> The mean daily milk production of machine-milked ewes in -M and -H groups (average of 1.8 kg) was 23% greater than that previously reported for Dorset ewes not treated with oxytocin (Treacher, 1971; Geenty and Davison, 1982). Production of ewes rearing twin lambs on similar allowances was 33-52% greater than for machine-milked ewes. Similar differences have been reported by Treacher (1971) and Geenty (1980) and the lower production of machine-milked ewes has been attributed to absence of the stimulus of lamb suckling and slow adaptation to machine milking.

Milk production of ewes rearing twin lambs showed a more pronounced peak than did that of machine-milked groups (Fig. 9.20), with maximum production of 2.5 kg/d for -L and 3 kg/d for -M and -H groups during week 3 of lactation. This peak in production probably reflects increasing suckling vigour and milk consumption of lambs until 2-3 weeks of age followed by a decline as they begin to consume herbage. Similar patterns and levels of production have been reported for ewes rearing twin lambs at pasture (Hadjipieris and Holmes, 1966; Peart <u>et al</u>.,1975; Maxwell <u>et al</u>.,1979; Geenty, 1979).

Despite differences in level of production between machine-milked and suckled ewes, the increases in milk yield to -M (average of 25%) and -H (average of 34%) compared with the -L allowance (Fig. 9.26), were similar for both categories of ewe. This suggests that milk yield
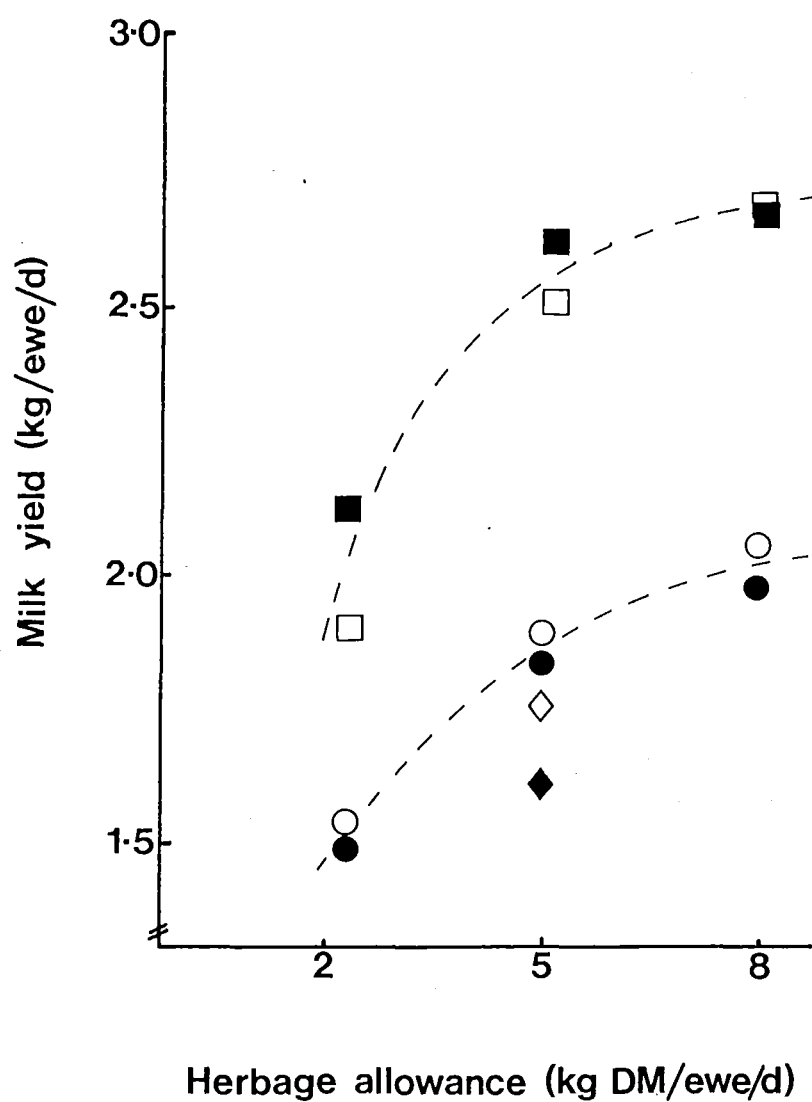
Figure 9.26:　Relationships between mean milk production and herbage allowance for machine-milked groups in Expt. A (L-, ○;　H-, ●) and Expt. B (L-, ◇;　H-, ◆) and suckled groups in Expt. B (L-, □;　H-, ■).

is largely determined by the milk removal characteristics of lambs or machines and the response to different herbage allowances is similar for each level of production. The smaller increment of milk yield between -M and -H groups (Fig. 9.26) indicates that the upper limit to production had been reached by suckled, and to a lesser extent, machine-milked ewes on the -M allowance.

The only other study with lactating ewes offered comparable allowances is that of Gibb and Treacher (1978). Ewes rearing twin lambs showed maximum daily production (2 kg/d) during the first 6 weeks of lactation on an allowance equivalent to that of the -M group.

Level of feeding during pregnancy had no influence on absolute milk production (kg/d) in either experiment though ewes in fat body condition (H-) had 12% lower average milk production per kg $W^{.75}$ (Tables 9.5 and 9.17) compared with lean ewes (L-). This corresponds with a lower feed intake by H- compared with L- ewes (discussed previously) and is associated with greater mobilization of body energy reserves in H- ewes. Other experiments have shown a lack of response of milk yield (kg/d) to increased nutrition during pregnancy (Peart, 1967,1970; Maxwell et al., 1979; Cowan et al.,1980a) though Treacher (1970) showed a response in machine-milked ewes at low levels of production. Stern et al (1978) found that a high level of food intake during pregnancy and heavy body condition of dairy ewes post-partum resulted in decreased food intake and suppression of milk yield.

9.23.3 Milk composition and energy yield. With the exception of low values for protein in Expt.B mean milk composition was within the range of published values

summarised in Table 9.25. Other studies with ewes at pasture have shown comparatively low milk protein concentration (Brett et al.,1972; Geenty, 1979) and Whiting et al (1952) found reduced milk protein with a low protein diet (7% CP). The tendency for higher milk fat concentrations with low feeding allowances during lactation was associated with greater body fat mobilization (Fig. 9.27). A similar result has been reported in the lactating ewe by Barnicoat et al (1949), Brett et al (1972) and Treacher (1971) while Gardner et al (1964) and Peart et al (1972) showed a greater milk fat content in milk from twin- compared with single-suckled ewes. A high level of feeding during pregnancy has increased milk fat concentration during early lactation in the dairy cow (Hutton and Parker, 1963; Davenport and Rakes, 1969; Lodge et al.,1975). The relationship between utilization of body fat reserves and increased milk fat has been attributed to increased fatty acid precursors for milk fat synthesis (Armstrong, 1968).

Variation in the energy content of milk during lactation in the present experiments showed a similar trend to total solids content. There was a gradual decline until week 6 in Expt.A and a decline during the initial 2-3 weeks followed by an increase with twin-suckled ewes in Expt.B. A similar trend to the latter was found with twin-suckled ewes by Peart et al (1972). The tendency for sheep on treatments which induced lower milk production to produce milk with a slightly greater total solids content meant that differences between groups in total energy yield were less than differences in milk production. A similar relationship was shown by Brett et al (1972).

Table 9.25 Composition of ewes milk in various studies

Source of data	Ewe breed	Lactation period (weeks from birth)	Measurement technique	Nutritional treatments	Single (S) twin (T) or triplet (Tr) suckled	Milk composition (g/kg)		
						fat	protein	lactose
Wallace (1948)	Border Leicester X Cheviot	2	S			75	46	49
Barnicoat et al (1949)	Romney	12	S			53	54	46
Whiting et al (1952)	Corriedale	7	S	7% protein diet		79	44	
				10% protein diet		85	48	
Owen (1957)	Welsh Mountain	10	S			61	57	50
Gardner et al (1964)	Rambouillet X Columbia	13	O	high plane	S	64	50	59
				high plane	T	76	53	59
				low plane	S	64	50	57
				low plane	T	72	52	55
Hadjipieris et al (1966)	Border Leicester X Cheviot	10	S	grass cubes	S	85	57	48
				grass cubes	T	65	54	49
				grass cubes and hay	T	66	53	48
				hay	S and T	73	48	46
				grazing	S and T	89	57	47
Corbett (1968)	Merino	10	O			84	51	53
Jagusch and Mitchell (1971)	Romney	3	O			68	62	45

(contd.)

Table 9.25 (contd.)

					+			
Treacher (1971)	Dorset Horn	6	M	low pregnancy		75		
				high pregnancy		81		
				low lactation		83	46	46
				medium lactation		81	51	47
				high lactation		68	52	48
Peart et al (1972)	Finnish Landrace							
	X Scottish Blackface	12	O		S	66	55	49
					T	71	54	51
					Tr	77	54	49
Brett et al (1972)	Merino	4 and 9	O	10 ewes/ha		69	49	52
				20 ewes/ha		74	50	52
				30 ewes/ha		74	50	51
Peart et al (1975)	Finnish Landrace							
	X Blackface	12	O		S	91	55	47
					T	87	55	47
					Tr	88	56	47
Geenty (1979)	Dorset, Corriedale							
	and Romny	12	O			88	48	38
Cowan et al (1980)	Finnish Landrace							
	X Dorset Horn	6	O	low pregnancy	T	75	55	57
				high pregnancy	T	82	52	57
Present study	Dorset	6	M	-L		71	53	51
				-M		65	53	50
				-H		66	53	50
			O and S	-L	T	79	40	51
				-M	T	78	40	52
				-H	T	71	39	48
			M	-Mm		71	47	48

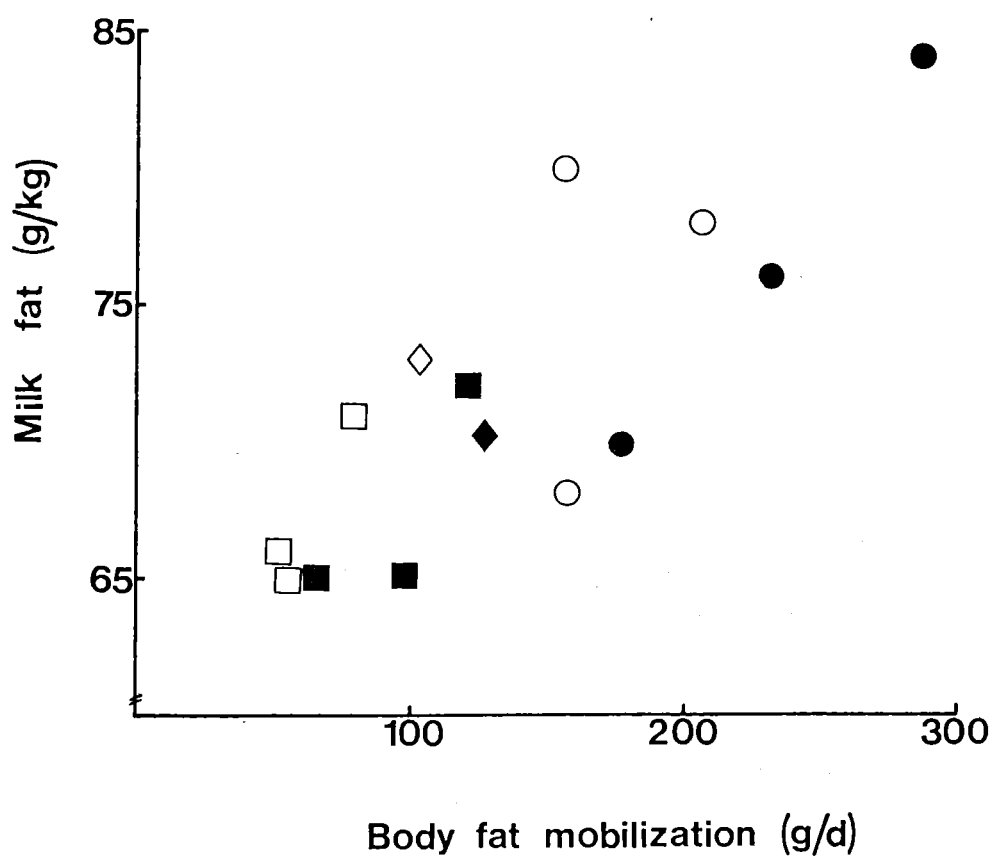+ S, lamb suckling; O, oxytocin and sample milking; M, machine-milking

Figure 9.27: Relationships between milk fat content and body fat mobilization for machine-milked groups in Expt. A (L-, O; H-, ●) and Expt. B (L-, ◇; H-, ◆) and suckled groups in Expt. B (L-, □; H-, ■).

The range of values for milk energy content between treatment groups (4.4-5.0 MJ/kg milk) was similar to that obtained by calorimetry in the study of Brett et al (1972) and the mean value for twin-suckled ewes (4.6 MJ/kg) was similar to the value obtained by Peart et al (1972).

9.24 Lamb growth.

In Expt.B there was an effect of herbage allowance during pregnancy on lamb birth weight and subsequent growth rate. The 11% greater weight at birth of lambs reared by H- compared with L- ewes was maintained until the end of week 6 despite no significant difference in milk yield (kg/d) between each class of ewe. Growth rate of lambs reared by H- ewes was 20 g/d greater than for those reared by L- ewes, a finding similar to that of Gibb and Treacher (1980).

The mean growth rate of 260 g/d by individual twin lambs in -M and -H groups, between birth and 6 weeks of age, was less than that in a previous study (320 g/d) with twin lambs of similar genotype (Geenty, 1979). Dorset ewes in the previous experiment produced more milk (3.5 kg/d), measured using the oxytocin technique, compared with the present experiment (2.6 kg/d), when they grazed similar pastures at a liberal herbage allowance. A possible reason for this difference, apart from seasonal effects, could be that the previous ewes were in a genetic improvement programme with intensive selection for lamb weaning weight so there may have been greater genetic potential for ewe milk production and lamb growth rate. Growth rates in -M and -H groups were within the range reported in other studies with twin lambs reared at

pasture including 241 g/d (Peart et al.,1975), 230 g/d (Gibb and Treacher, 1978), 300 g/d (Maxwell et al.,1979) and 260 g/d (Gibb and Treacher, 1980).

Reduced overall growth rate (209 g/d) of lambs in the -L group occurred mainly during weeks 5 and 6 of lactation, presumably due to lower milk production and competition for available herbage by ewes. A similar depression of lamb growth was shown at comparable allowances by Gibb and Treacher (1978). During the final 2 weeks of lactation, in the present experiment, ewes in the -L group consumed approximately 1.1 kg OM/ewe/d, and, ignoring herbage accumulation, there would have been an approximate herbage allowance of .9 kg OM/d for lambs (i.e. .5 kg OM/lamb/d). This herbage would have been of relatively low nutritive quality, owing to the selective grazing of ewes. From visual observation ewes in this group defoliated the sward rapidly during the first of each 3 day grazing interval so lambs would have had little opportunity to selectively graze high quality herbage. Twin lambs in -M and -H groups, during the same period, would have had corresponding allowances of about 1.5 and 3.0 kg OM/lamb/d respectively, and of relatively higher quality.

Intercept values in regressions (p 110) of lamb live weight gain on milk production (5.7, 8.8 and 11.8 in -L, -M and -H groups respectively) suggest a progressively greater contribution of herbage to lamb growth in -M and -H groups. The regression coefficients indicate, however, greater quantities of milk per unit of lamb body weight gain in -H (10.8) compared with -M (8.5) and -L (7.0) groups. These results suggest either overestimation of milk production or reduced "efficiency" of utilization of

milk for growth in -M and -H groups. Comparisons of efficiency with other studies can be made from simple ratios of mean milk production:lamb body weight gain during the initial 4-6 weeks of lactation but these will include the contribution of herbage or food supplements to lamb growth. Values of 4.7, 5.0 and 5.0 in -L, -M and -H groups respectively, were, however, generally slightly lower than other estimates for twins at pasture, based on oxytocin measurement. These include 4.1-5.0 (Gibb and Treacher, 1978), 5.1-5.8 (Geenty, 1979) and 4.9-6.1 (Gibb and Treacher, 1980). Equivalent ratios for twin lambs reared indoors, include 3.6-4.6 (Peart, 1968, 1970) and 5.7-6.7 (Cowan et al.,1980a) with milk production measured by lamb suckling and oxytocin techniques respectively.

9.25 Ewe body weight.

9.25.1 Pregnancy. The objective of a maternal body weight difference post-partum of 10-15 kg between L- and H- groups was almost achieved during mid-pregnancy (i.e. by week 16) in both experiments. In Expt.A, however, a delay in weight gain in the L- group until the final 4 weeks of pregnancy was associated with symptoms of ketosis in a small number of ewes. Increased herbage allowances in both groups during late pregnancy were considered necessary both to avoid metabolic disorders and ensure lamb and ewe viability.

In both experiments there was a similar decrease in mean litter weight at birth of 16% in L- compared with H- groups. This suggests there was a similar degree of undernourishment in L- groups in both experiments. Russel et al (1977) showed that moderate to severe

undernourishment of housed ewes, bearing single or twin lambs, caused a decrease in ewe body weight of 10-15 kg at term and decreased lamb birth weights of 21-26%. The relatively smaller difference in lamb birth weight between pregnancy treatments in the present experiments, despite a similar difference in ewe body weight at term, may have been due to the absence of different feeding levels during the final month of gestation. Rattray et al (1980) and Rattray and Trigg (1979) showed that differential feeding during mid-pregnancy influences foetal growth during late pregnancy, but that the extent of differences may be reduced by liberal feeding in late pregnancy. It was suggested by Robinson (1982), however, that a significant reduction in lamb birth weight would occur if ewe body weight was reduced by 20% during mid-pregnancy and increased nutrition was delayed until the final 4 weeks of pregnancy. In a review, he indicated that feed intake below .5-.6 MJ ME/kg $W^{.75}$/d during late pregnancy tends to reduce lamb birth weight by at least 10%.

9.25.2 Lactation. The influence of variation in gut fill on body weight during lactation would have been considerable owing to rotational grazing and lack of standardised fasting periods before weighing. Fasting was avoided to prevent interference with grazing and depression of production. Effects of gut fill may have been minimised, however, in Expt.A by routinely weighing after morning milkings (i.e. 2-3 h off pasture) on the final day of each 3 day grazing period. A similar routine was not possible in Expt.B and body weights during weeks 2 and 5 were recorded approximately 24 h after ewes had commenced a new grazing period, compared with 48 or 72 h later on other occasions. This probably accounted for the

inflated weights during weeks 2 and 5 (Fig. 9.23).

Mean body weights generally showed an increase during the initial 3 weeks of lactation followed by a decline, with an overall trend of weight loss. The initial increase in body weight can be largely attributed to gut-fill as feed intake increases (Peart, 1970).   The effect of increasing gut-fill on apparent increase in body weight was shown by Graham and Williams (1962) to be proportionately greater than suggested by intake. They calculated from the rate of passage of digesta and D of a hay-concentrate diet that an increase in food intake from 1.0 to 1.5 kg DM/d would increase DM content of the gut from 1.5 to 2 kg DM/d and Cowan et al (1979) confirmed this effect. The daily intakes of ewes in the present experiments ranged from 1.5 to 2.8 kg DM/d, and with a mean DM content of 160 g/kg, the range in intake of green material would have been 9.4-17.5 kg/d.   It is thus probable that considerable variation in weight of gut contents existed during 3 day grazing periods.   Any cumulative effects on body weight as discussed above, may however, be less on fresh herbage diets which have a relatively faster rate of passage.

The findings here and in other experiments underline the importance of adopting a regular weighing routine, for measurement of body weight trends with the lactating ewe at pasture, particularly with regard to grazing management and time off pasture before weighing (Hughes, 1976).   Accurate measurement of body weight changes require periodic standardised fasting periods or use of comparative slaughter.

Body weight losses of ewes during early lactation have frequently been reported both at pasture (Peart et al.,1975; Gibb and Treacher, 1978,1980) and indoors (Peart, 1970; Peart et al.,1972; Cowan et al.,1980a) although increases with the grazing ewe have been observed (Langlands, 1973; Maxwell et al., 1979). The extent of body weight reductions have generally been greatest with ewes rearing more than one lamb, those at high levels of milk production, those in relatively heavy initial body condition and where nutrition during early lactation has been restricted.

It is therefore surprising in the present experiments that relatively low producing machine-milked ewes in -M and -H groups showed body weight losses. This may be due to metabolic regulation of intake according to level of milk production as discussed on p 129. It is possible this characteristic may be specific to the Dorset breed suggesting caution may be required in extrapolation of results to other breeds.

9.26 Body composition.

9.26.1 Chemical composition.

Measurement of changes in body fat and protein contents during lactation relied on initial prediction in live ewes using equations from comparative slaughter groups. This was done with average RSD's of 1.92 kg fat and .34 kg protein. Coefficients of variation showed that a very high (90%) proportion of variation in both components was explained by variation in fasted body weight.

Rate of body fat loss during lactation (Figs. 9.14 and 9.24) between groups was influenced by fat content post-partum, herbage allowance during lactation and level of milk production. Ewes in fat body condition post-partum and rearing twin lambs on a low herbage allowance showed greatest fat mobilization of 287 g/d. This compares with values of 283 g/d (Cowan et al.,1979) and 336 g/d (Cowan et al.,1980a) for lactating ewes offered complete roughage-concentrate diets indoors. Initial body fat content of H- ewes in the present experiments (14.7 and 18 kg) were slightly less than the value of 19 kg in the experiment of Cowan et al (1980a).

There was a proportionately greater loss of fat from internal depots than from the carcass in both experiments, the ratio of internal:total body fat decreasing from about .21 in early pregnancy to .16 post-partum and .13 at the end of lactation (Tables 9.8 and 9.21). Ratios decreased with decreasing herbage allowance suggesting that the proportional rate of loss from internal depots increased as total body fat decreased.

Similar relationships between losses of total and internal fat have been reported in dry (Russel et al.,1971) and lactating ewes (Cowan et al.,1980a). Lister (1976) showed breed and species differences in proportions of total body fat stored in some internal fat depots and Geenty et al (1979) found that Dorset cross sheep partitioned relatively more fat to internal depots during growth than did other breeds. The proportions of internal fat in the present ewes during weeks one and 6 of lactation (16% and 13% respectively) were considerably lower than corresponding values of Cowan et al (1980a) for

Finnish Landrace X Dorset ewes (29% and 27% respectively). The Finnish Landrace appears to have a very low ratio of subcutaneous:internal fat (Lister, 1976).

The extent of depletion of total body fat during pregnancy in L- groups (45% and 53% in Expts.A and B respectively) were moderate compared with losses of over 80% in severely undernourished ewes (Russel et al.,1968; Field et al., 1968; ·Sykes and Field, 1972; Lodge and Heaney, 1973) thus leaving substantial (8-10 kg) body fat post-partum. Loss of body fat in apparently well nourished H- ewes (4% and 13% in Expts.A and B respectively) indicate the difficulty of maintaining body fat reserves of pregnant ewes at pasture during winter, even with generous allowances.

There was little loss of body protein in L- ewes during lactation suggesting labile body protein reserves were depleted during pregnancy (Figs. 9.14 and 9.24). Losses during lactation in H- groups, averaged 30 g/d for twin-suckled and 19 g/d for machine-milked ewes. The highest rate of 43 g/d in HL ewes rearing twins was greater than the highest value of 26 g/d found by Cowan et al (1980a) with ewes offered a low energy diet during early lactation. Rate of body fat mobilization was also greatest and ME intake lowest (17.1 MJ ME/ewe/d) in the HL group. The large quantities of fatty acids from mobilized body fat would have required a source of protein to be utilized for milk production. It is difficult, as discussed later (p 163), however, to judge whether the supply of amino acids from dietary protein limited milk production. Robinson et al (1979) and Cowan et al (1981) have shown increased utilization of body fat reserves for milk production in ewes on a low energy diet supplemented

with protected protein.

There were increases in water content of the fat-free empty bodies of ewes, mainly during pregnancy, and these resulted in progressive increases in water:protein ratios during pregnancy and lactation (Tables 9.8 and 9.21). The increases tended to be greatest with ewes on a low plane of nutrition during both pregnancy and lactation and were of a similar order to those observed by Cowan et al (1980a) during early lactation. This result may have been due to increased extracellular fluid which is sometimes associated with undernutrition (see p 12).

9.26.2 Energy content of body weight change. Estimates of body energy change in the ewe during lactation are often based on body weight change and assumptions on energy content (Langlands, 1977; Maxwell et al.,1979). Mean values for treatment groups in the present study were calculated on the basis of body weight and empty body weight prior to slaughter, at the beginning and end of lactation (Table 9.26).

With one exception L- groups showed relatively greater values for the energy content of both body weight and empty body weight change reflecting the lower gut-fill and increased water and protein components of change in H-groups. Large variation in the energy content of body weight change (24-90 MJ/kg) was also found in lactating ewes by Cowan et al (1980a) and in lactating dairy cows by Moe et al (1971). Use of body weight alone as an accurate indication of energy status in the lactating ruminant is thus clearly precluded.

Table 9.26 The energy content (MJ/kg) of change in
            ewe body weight and empty body weight
            during lactation (Expts.A and B)

EXPERIMENT A

Treatment

Energy content of	LL	HL	LM	HM	LH	HH
body weight change	·136	36	89	56	−37+	41
Energy content of						
empty body weight change	31	22	23	24	59	19

EXPERIMENT B

Treatment

	LL	HL	LM	HM	LH	HH	LMm	HMm
Energy content of								
body weight change	53	33	87	44	120	45	140	65
Energy content of								
empty body weight change	32	26	42	30	47	28	47	33

+ group showed positive weight gain

9.26.3 Weights of body parts.

Smith and Baldwin (1974) showed that in dairy cows, the liver and gastrointestinal tract are heaviest during early lactation and are the most metabolically active organs. Weights of these organs in the present experiments were heaviest post-partum (Tables 9.7 and 9.20) and, although weights generally declined by week 6, showed positive responses to nutrition during lactation. Wallace (1948) and Robinson (1948) showed in sheep that the liver was one of the most sensitive organs to nutritional change and Cowan et al (1979, 1980a) found decreases in liver weights of ewes by week 6 of lactation.

The relatively small differences in weight of the mammary gland post-partum between pregnancy allowance treatments, possibly reflects the lack of nutritional difference between groups in late pregnancy. The 27% greater weight of mammary gland for H- compared with L- ewes in Expt.B is consistent with, though much less in magnitude, than the two-fold greater udder weight recorded by Rattray and Trigg (1979) in twin-bearing ewes on a high compared with a low allowance during late pregnancy. Ewes giving birth to twin lambs had 20% (2.41 ± .274 kg) and 22% (1.70 ± .128 kg) heavier udders post-partum than those with singles in Expts.A and B respectively, a difference which had dissappeared by week 6. The initially greater udder weights of twin-bearing ewes were associated with increased average milk yields of 11% (1.84 ± .07 kg/d) for machine-milked and 13% (2.5 ± .09 kg/d) for twin-suckled ewes. These differences are real effects of pregnancy status, independant of lamb rearing effects, and are much smaller than those for ewes giving birth to and rearing twins compared with singles (Wallace 1948; Coop and Drew,

1963; Peart, 1967; Peart et al.,1972; Geenty, 1979). Dorset ewes with twins have shown up to 70% greater milk yield than those with singles (Geenty, 1979).

These differences in milk yield between single- and twin-bearing ewes, are small when milk demand is determined by machine-milking or twin-suckling, suggesting production limits are set largely by milk removal characteristics of machines or lambs. This was illustrated further by the higher milk production of twin-suckled (Expt.B) compared with machine-milked ewes (Expt.A).

The association of udder size with milk yield, for each category of ewe, is shown by the following relationships between dissected udder weight at week 6 (X, kg) and milk yield (Y, kg) -

$$\begin{array}{lccc} & & RSD & r^2 \\ \text{Expt.A (machine-milked)} & Y = 1.04X + 0.259 & 0.253 & .67 \\ (n = 70) \\ \text{Expt.B (twin-suckled)} & Y = 0.76X + 1.41 & 0.484 & .23 \\ (n = 58) \end{array}$$

The closer association for machine-milked compared with twin-suckled ewes may have been due to the more uniform removal of milk by machines compared with lambs in addition to more precise measurement of milk production.

9.27 Partitioning of energy.

The partitioning of MEI between MEm and milk production, and the contribution of body energy to milk production, was determined by multiple regression, using power functions of empty body weight ranging from 0.6 to

0.8. Error variances for alternatives were similar and the 0.75 exponent was therefore adopted. Since inclusion of an intercept in regressions had no influence on residual errors, regressions were constrained through the origin.

The grouping of ewes for multiple regression according to treatment during pregnancy makes the assumption of no interactions between pregnancy and lactation nutrition treatments for maintenance requirement and efficiency estimates. Numbers of sheep in individual treatment groups did not allow this to be checked by separate regressions. Furthermore, the statistical partitioning of energy assumes linearity of changes in body energy during lactation, which again, cannot be checked in the absence of intermediate observations. Reassurance of the repeatibility of results between years was, however, given by similar mean values for machine-milked ewes in both experiments (Tables 9.10 and 9.23).

9.27.1 <u>Maintenance requirements.</u> Estimates varied little between pregnancy nutrition groups from an average value of .640 MJ ME/kg $W^{.75}$/d (.235 MJ ME/kg W/d) except for a 17% lower requirement for L- compared with H- ewes in Expt.A. With the exception of this group, estimates were within the range of previously reported values for lactating ewes at pasture (MJ ME/kg W/d) including .244 (Langlands and Bennett, 1973), .218 (Langlands, 1977) and .242 (Maxwell <u>et al.</u>,1979).

The reason for the apparently lower MEm requirement in L- ewes machine-milked is difficult to explain. It was associated with a low average rate of body energy loss

(2.7 MJ/ewe/d) compared with H- ewes machine-milked (4.0 MJ/ewe/d) or suckled (7.7 MJ/ewe/d). Reduced maintenance requirement in sheep as a result of undernutrition has been reported in a calorimetric study by Gingins et al (1980) using adult wethers. Estimates were 26% lower during undernutrition and negative energy balance compared with during realimentation.

The energy requirement for wool synthesis has been included with MEm. Yeates et al (1975) suggested it approximates the combustible energy of greasy wool. Assuming values of 25.5 and 40.8 MJ/kg for clean wool and wax, respectively (ARC, 1980), ewes in the present study would have used about 0.1 MJ ME/d for wool production, a very small proportion of MEm.

9.27.2 Utilization of ME and body energy for milk production. The 17% lower MEm of L- ewes in Expt.A was associated with a 25% lower K_1 value for L- compared with H- ewes i.e. proportionately more ME was apparently partitioned to milk synthesis. Moe and Tyrrell (1975) similarly showed in dairy cows a decrease of 16% in MEm in association with a 13% decrease in K_1. The greater average value of K_1 for machine-milked (.84) compared with suckled ewes (.65) in the present work was associated with a 5% lower average maintenance requirement (.604 MJ ME/kg $W^{.75}$/d) and a lower efficiency of utilization of body energy reserves (.29 compared with .45) for milk synthesis.

There are no other data in which efficiency in the lactating ewe has been estimated using comparative slaughter and multiple regression with which the present results can be compared. Most of the studies discussed

below have used assumed values of MEm and indirect estimates of body energy change based on body weight. Furthermore, assumptions have invariably been made on the efficiency with which mobilized TSE is used for milk production and thus the extent of the sparing effect on MEI.

Calculations from a calorimetric study by Graham (1964) gave a K_1 value of .65. Gardner and Hogue (1964) found values of .66 and .82 for ewes rearing single and twin lambs respectively and in a later experiment (Gardner and Hogue, 1966) showed differences in K_1 between Hampshire (.75) and Corriedale (.90) ewes. Other estimates of K_1 have included .73 (Hadjipieris et al.,1966), .66 (Langlands, 1977), and .59 (Maxwell et al.,1979). Re-analysis of data from several experiments by Robinson (1978) gave an average K_1 value of .63.

In the dairy cow, estimates from a large number of calorimetric studies, show average K_1 values of .66 and .63 respectively for cows in negative and positive energy balance (Moe et al.,1971). In the same studies body energy reserves were utilized for milk production with a comparatively high efficiency of .82. The only comparison available in the ewe is a comparative slaughter study by Cowan et al (1980a), in which body reserves were calculated to have been utilized with an efficiency of less than .50, in agreement with the present study.

9.27.3 Comparison of individual treatments. The mean efficiency of use of ME and TSE $(K_{1(t)})$, for individual treatment groups, was calculated on the assumption of common MEm values, derived from the regressions within pregnancy treatment groups, and

assuming that all mobilized TSE was available for milk synthesis, using the following expression -

$$K_{l(t)} = MKE/[MEI - MEm] + TSE$$

Resulting $K_{l(t)}$ coefficients were converted to reciprocals, to improve homogeneity of variance, and treatments compared by analysis of variance. Component means and back-transformed coefficients are given in Table 9.27.

As would be expected, estimates of $K_{l(t)}$ were 19% lower for L- compared with H- ewes in Expt.A, corresponding with a 25% lower (MJ/ewe/d) average MEm of L- ewes. Apart from this, pregnancy or lactation nutrition appeared to have little effect on $K_{l(t)}$. To examine this in more detail the $K_{l(t)}$ values for individual treatment groups have been plotted against TSE loss (Fig.9.28). Within experiments there was a trend for increasing efficiency with increasing TSE mobilization, whereas when experiments were combined, there was an overall trend for decreasing efficiency with increasing energy mobilization. Values estimated in a similar way, but with assumptions on MEm (Cowan et al.,1980a), are superimposed in Fig. 9.28. These values fall within the ranges observed and show a similar declining trend with increasing body energy loss.

In view of the varying quantities of body protein and fat mobilized, the relative proportions of TSE derived from these tissues were calculated. The intercept value (a) in the regression of body energy content (MJ/kg W) on body fat content (g/kg W) (Fig. 9.13) was used to calculate the energy content of protein (A, MJ) from protein concentration in the FFEB (B, g/kg) (assuming

Table 9.27   Effect of herbage allowance during pregnancy and lactation on energy balance (MJ/d) and efficiency of milk energy production during the first 6 weeks of lactation

EXPERIMENT A

	Pregnancy allowance		Lactation allowance			SD	Significance tests	
							Pregnancy effects	Lactation effects
	-L	-H	L-	M-	H-			
ME intake	22.4	21.5	19.4	22.4	24.1	2.52	NS	**
Maintenance requirement	10.6	14.2	12.3	12.5	12.8			
ME above maintenance	11.8	7.2	6.9	9.7	11.3			
Maternal tissue energy loss	2.7	4.0	4.3	3.2	2.6	2.52	*	NS
Total energy available	14.5	11.2	11.2	12.9	14.0	3.75	**	*
Energy output in milk	8.8	8.4	7.4	8.8	9.5	1.83	NS	**
$K_{1(t)}$	.60	.75	.65	.68	.70	.351	**	NS

EXPERIMENT B

|	Pregnancy allowance		Lactation allowance			SD	Significance tests		-Mm	SD
							Pregnancy effects	Lactation effects		
	L-	H-	-L	-M	-H					
ME intake	22.9	22.8	17.3	23.4	27.7	3.25	NS	**	21.0	2.76
Maintenance requirement	11.6	13.5	12.4	12.5	12.7				12.9	
ME above maintenance	11.2	9.4	4.9	10.9	15.0				8.0	
Maternal tissue energy loss	7.2	10.1	10.7	8.2	7.1	3.51	**	*	4.9	2.75
Total energy available	18.5	19.5	15.7	19.2	22.1	4.76	NS	**	12.9	2.92
Energy output in milk	10.8	11.3	9.4	12.0	11.7	2.29	NS	**	8.2	1.21
$K_{1(t)}$	.60	.59	.59	.63	.53	.320	NS	*	.62	.387
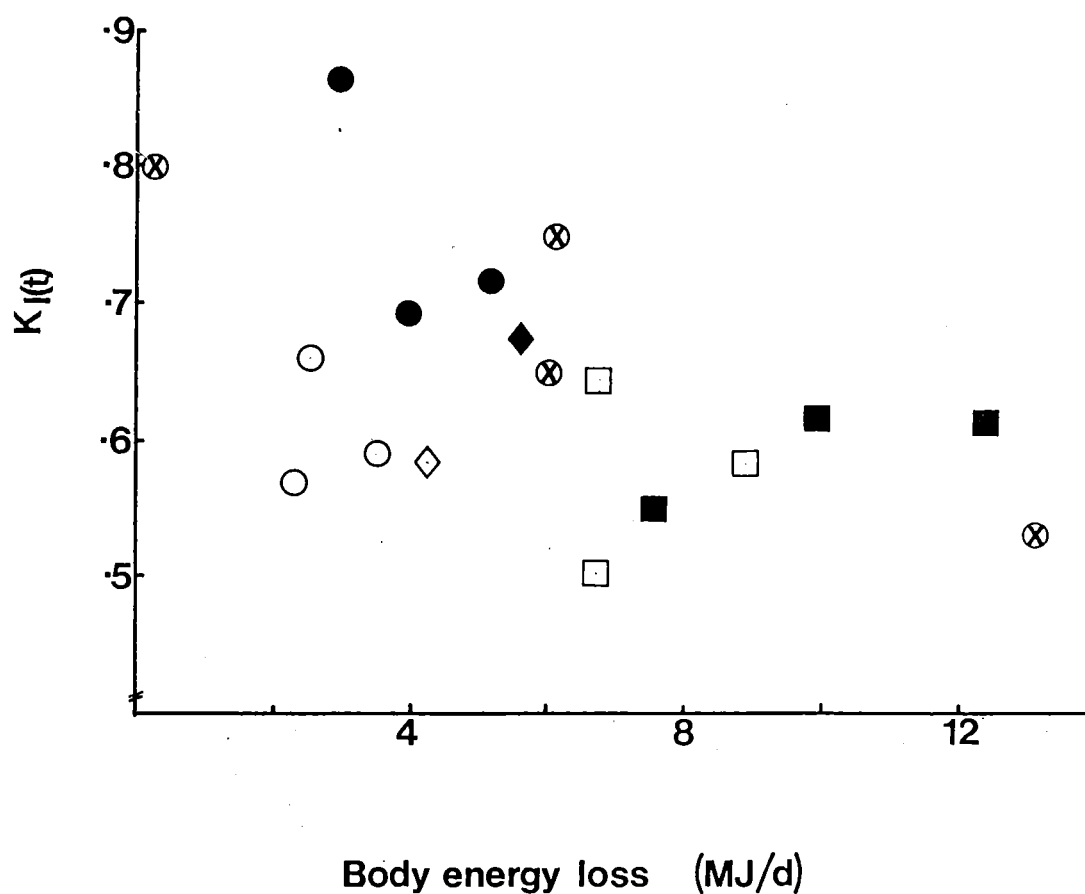
Figure 9.28: Relationships between efficiency of milk

production ($K_{1(t)}$) and body tissue energy

loss for machine-milked groups in Expt. A

(L-, O; H-, ●) and Expt. B (L-, ◇; H-,

◆) and suckled groups in Expt. B (L-, □;

H-, ■) with data of Cowan et al. (1980a)

superimposed (⊗).

protein was the only energy component in the FFEB) i.e. at zero body fat -

$$A = a \times 1000/B$$

The energy content of fat could then be obtained by difference (i.e. fat energy = body energy - protein energy). Mean values obtained were 17 MJ/kg for protein and 40.9 MJ/kg for fat These compare with theoretical values respectively of 23.6 and 39.3 MJ/kg (ARC, 1980).

A positive relationship between the proportion of mobilized TSE from body protein and $K_{1(t)}$ for individual treatments, is shown for data from both experiments combined in Fig. 9.29. Such a positive relationship has not been previously shown in the lactating ruminant. The data of Cowan et al (1981) show, however, that a low protein diet (116 g CP/kg DM) was associated with a reduced $K_{1(t)}$ during weeks 3-6 of lactation. Maintenance of high $K_{1(t)}$ values during weeks 1-3, despite a low protein diet, suggested that labile body protein reserves may have contributed.

Several experiments have shown milk production responses to increased dietary protein. Supplementation with fish meal protein protected against degradation in the rumen by heat treatment (Robinson et al.,1979; Cowan et al.,1981) caused increased milk yield in fat ewes with greater utilization of body fat reserves. Moreover, Barry (1980) showed an increase in milk yield as a result of abomasal infusion of casein in ewes offered fresh herbage.

In the present experiments, body protein mobilization during lactation was considerably greater, on average, in H- compared with L- ewes, and this corresponds
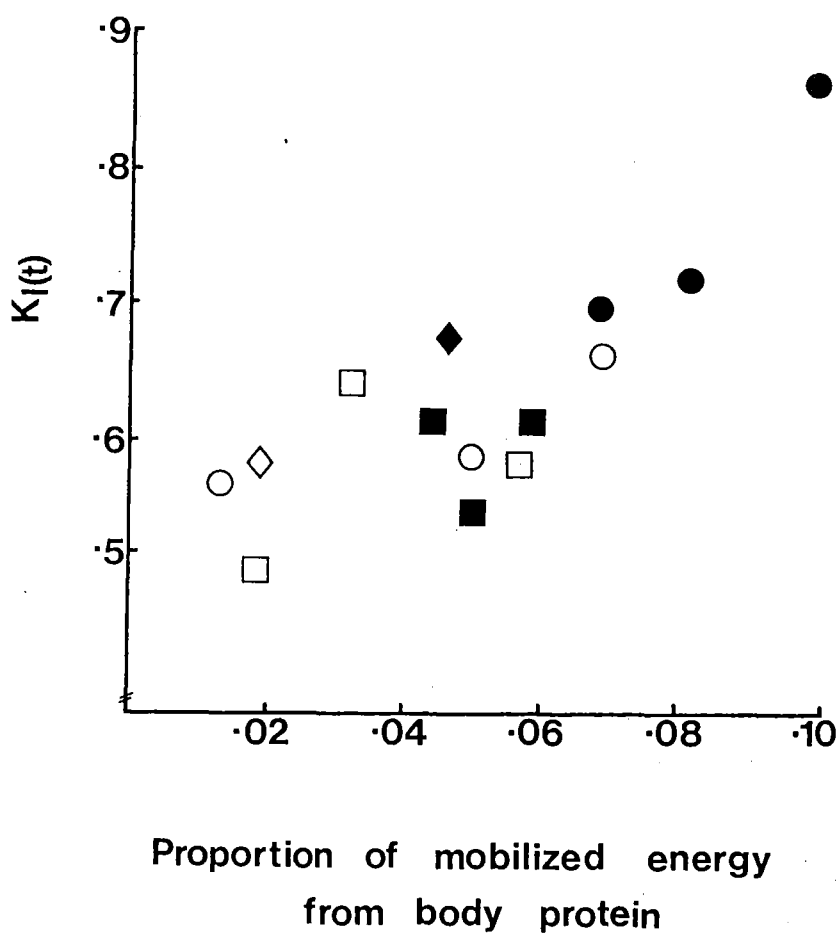
Figure 9.29: Relationships between efficiency of milk production ($K_{1(t)}$) and proportion of mobilized energy from body protein tissue for machine-milked groups in Expt. A (L-, O; H-, ●) and Expt. B (L-, ◇; H-, ◆) and suckled groups in Expt. B (L-, □; H-, ■).

with the greater efficiency of TSE utilization for milk synthesis in this group. Coppock et al (1968) reported that lactating ruminants can utilize around 10% of total body protein to sustain milk production during early lactation. It is probable that in the present experiments, a high proportion of labile body protein reserves were depleted during pregnancy in L- ewes which had lost 15-20% of total body protein by parturition. The small quantitative contribution of tissue protein to energy for milk production (less than 10% of mobilized TSE) suggests the effect on efficiency, if real, may have been qualitative i.e. specific amino acids essential for milk synthesis supplied from tissue protein.

A lack of data for rumen degradability of dietary protein and microbial protein synthesis in the lactating ewe at pasture make quantitative estimates of the availability of dietary protein for metabolism difficult. Using a range of values for degradability (.7-.9) and microbial synthesis (20-50 g N/kg DOM), Hughes et al (1980) have calculated that herbage diets may not provide adequate amino acids for the lactating ewe. Furthermore, Barry (1980) suggested that lactating ruminants, even when consuming ad-libitum high quality herbage diets, may not necessarily absorb amino acids in excess of their requirement for production.

The interrelationships suggested between TSE mobilization, and the proportion from body protein, with $K_{1(t)}$ in the present experiments, should be treated with caution. Trends were obtained from two experiments, during different seasons, and with Dorset ewes both machine-milked and suckled by twin lambs. Furthermore, the suggestion of a lower MEm in lean compared with fat

ewes, was evident in only one of the experiments and in ewes machine-milked.

9.27.4 Energy requirements. The most comprehensive feeding tables for the lactating ewe which can be used for comparison with the present results, are those of ARC (1980). Ratio of MEI:ARC theoretical requirement at zero body weight change) for individual treatment groups in Expts. A and B are plotted against body energy balance in Fig. 9.30. In general MEI showed a progressive decrease in relation to ARC requirement, with increasing body energy loss, reflecting the increasing contribution of body energy reserves to milk production. Agreement between the present results and ARC requirements would be indicated if a regression line passed through 1.0 on the Y axis. Extrapolation of the data show, however, that the intercept would be between 1.1 and 1.2 suggesting that MEI was approximately 15% greater than ARC recommendations. It appears that this discrepancy is due largely to greater MEm values found in the present work (.205-.245 MJ ME/kg W/d) compared with values apparently used by ARC of about .148 MJ ME/kg W/d. Variation about the regression line in Fig. 9.30 is probably caused by the wide range of $K_{l(t)}$ values between groups in the present study (.51-.84). In general, groups with high $K_{l(t)}$ values, particularly H-ewes with low milk production, were below the line, and groups with low $K_{l(t)}$ values, those which had lost body reserves during pregnancy and with high milk production, were above the line.

In order to compile a feeding table from the present results, ME requirements for machine-milked and twin-suckled ewes, in lean (L-) or fat (H-) body condition at the start of lactation, and losing varying quantities
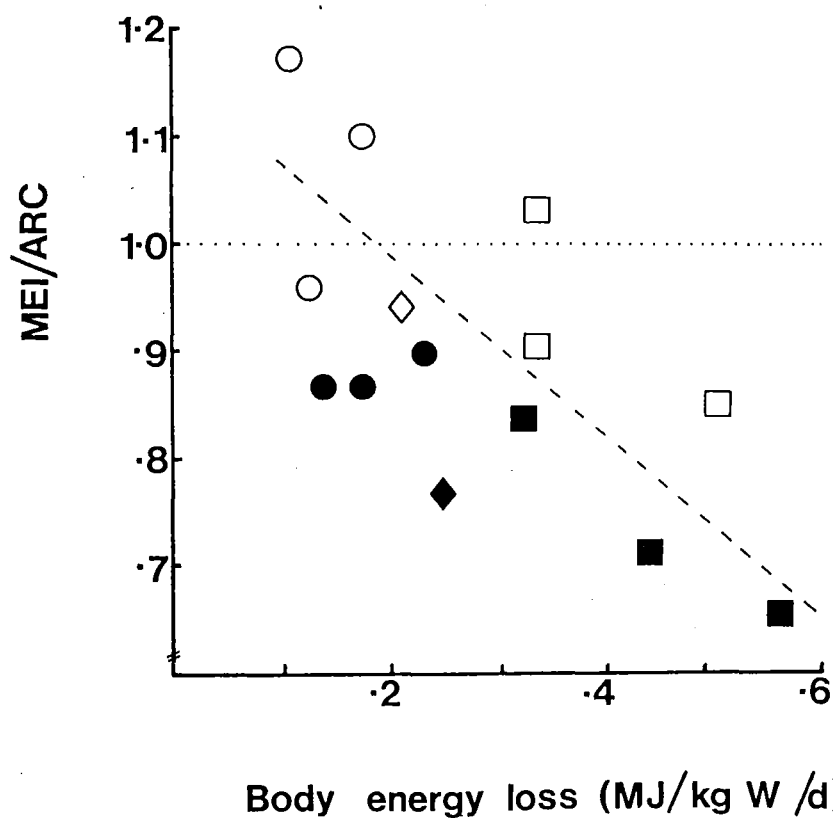
Figure 9.30: Relationships between the ratio of measured MEI: theoretical energy requirement (ARC, 1980) and body energy mobilization for machine-milked groups in Expt. A (L-, ○; H-,●) and Expt. B (L-, ◇; H-, ◆) and suckled groups in Expt. B (L-, □; H-, ■).

Table 9.28 Metabolizable energy requirements (MJ ME/d) of small, medium or large ewes in lean or fat body condition during early lactation, calculated from results of the present study

Category of ewe	Ewe body weight at parturition (kg)	Body energy change during lactation (MJ/d)	Milk yield (kg/d)	
			1.5+	2.5++
Small	40 (lean)	−3	17.9	25.6
		−6	16.9	23.8
	50 (fat)	−3	18.7	27.7
		−6	17.5	25.3
		−9	16.4	23.0
Medium	50 (lean)	−3	19.5	27.5
		−6	18.5	25.7
	60 (fat)	−3	20.5	29.4
		−6	19.4	27.1
		−9	18.3	24.7
Large	60 (lean)	−3	21.1	29.3
		−6	20.1	27.6
	70 (fat)	−3	22.2	31.0
		−6	21.1	28.7
		−9	20.0	26.3

+ for machine-milked ewes (equivalent milk production of single-suckled)

++ for twin-suckled ewes

of body energy, were calculated using the appropriate regression equations. Values are for ewes with mature body weights of 50 (small), 60 (medium) or 70 kg (large) at mating, either maintaining these maternal body weights until parturition (fat) or losing 10 kg during pregnancy (lean). Results are given in Table 9.28.

Estimated requirements (MJ ME/kg W/d) appear 10-12% greater than ARC (1980) recommendations, particularly for lean ewes losing 3 MJ TSE/d but are closer for fat ewes losing 3 or 6 MJ TSE/d.

Daily ME requirement for ewes which had maintained body weight (fat) between mating and parturition are 5-8% greater than for those which had lost 10 kg (lean) during pregnancy. The lower requirement of lean ewes, however, needs to be weighed against the energy cost of replacing depleted body energy reserves by the subsequent mating. There is little difference in daily requirement of fat compared with lean ewes, at the same body weight, at the high level of milk production. In contrast to the hypothesis of Peart (1967, 1968, 1970), however, that lean ewes may be more efficient in terms of feed requirement for milk production than fat ewes, lean ewes in the present study had greater energy requirement than fat ewes, when compared at the same body weight and at the lower level of milk production.

10. CONCLUSIONS

The chromic oxide dilution technique appeared satisfactory for measurement of feed intake of the grazing ewe. The necessity to include total faecal collection to check for bias with grab-sampling and use of O/F ewes to determine diet selection, were highlighted, however.

Estimation of milk production in ewes rearing lambs, by sample measurement, was not as precise as direct measurement in machine-milked ewes. Use of a combination of lamb-suckling and oxytocin techniques were preferable to each individually, however, and final estimates appeared satisfactory in relation to lamb growth and probably showed little bias among treatments.

The attainment of maximum feed intake during the initial weeks of lactation suggests bulk limitation did not exist on the highly digestible swards used. This, along with negative energy balance of ewes in all groups, indicates that feed intake was probably regulated metabolically, according to level of milk production. It appears, then, that milk demand by lambs or machines, sets potential limits to feed intake which, in turn, is influenced by herbage availability. A residual herbage mass below 800 kg DM/ha would appear to restrict intake during early lactation.

The level of milk production appeared to be set by the removal characteristics of lambs or machines, production being considerably lower for the latter. Responses of both categories of ewe to increasing herbage allowance were similar, however, with near maximum

production achieved on the -M allowance (5 kg DM/ewe/d). Mean growth rates of lambs, during the 6 week lactation, similarly showed near maximum values on the -M allowance. These results suggest there is little advantage, in terms of milk production and lamb growth, of offering machine-milked, or ewes with twin lambs, a herbage allowance greater than 5 kg DM/ewe/d. This may not, however, apply after week 6 of lactation with the latter when herbage requirements of lambs increase. The greater lamb birth weight for H- compared with L- ewes and better subsequent lamb growth rate (+20 g/lamb/d), indicate some advantage of generous feeding of the ewe during pregnancy.

The ability of the lactating ewe to mobilize body fat reserves was evident in both experiments. It appears that the grazing ewe goes into negative energy balance during early lactation, regardless of level of milk production and nutrition. Losses of fat were greatest in groups previously on a high allowance during pregnancy and with the heaviest body fat reserves post-partum, at high levels of milk production (i.e. rearing twin lambs), and offered a low herbage allowance during lactation. The extent of body protein mobilization during lactation was also greatest in ewes offered a high allowance during pregnancy and a low allowance during lactation. It appears that a low plane of nutrition during pregnancy depletes labile body protein reserves which, if present, are readily utilized for milk production during early lactation. Associated with body protein losses during pregnancy and lactation were concurrent increases in body water and increased water:protein ratios.

The chemical changes in the empty body during early lactation, and varying changes in gut-fill between treatments, both independantly of body weight of the live animal, caused large variation in the energy content of body weight change. This is clearly an obstacle in determination of energy change, using body weight of the ewe, during early lactation.

Validity of the present results on the partitioning of energy and efficiency, depend partly on assumptions inherent in the statistical model used. It was reassuring, however, that estimates of maintenance energy requirements, with the exception of L- ewes machine-milked, were similar to those previously reported for the lactating ewe at pasture. In addition, results with machine-milked ewes were repeatable between years.

Efficiency of milk production showed large variation between treatment groups, particularly with machine-milked ewes where values were greatest in groups showing lowest body energy mobilization during lactation. The low efficiency of use of body energy reserves for milk production in the ewe ($<.50$) compared with in the dairy cow ($.82$), may partly account for the comparatively greater variation in $K_{1(t)}$ in the ewe. In addition to the tendency for decreasing efficiency among groups, with increasing body energy loss, there was a stronger positive association between efficiency of milk production and the proportion of mobilized body energy from tissue protein. This suggests that restricted feeding of the ewe during pregnancy, and depletion of labile body protein reserves, may reduce $K_{1(t)}$ during early lactation. The apparent response in efficiency to mobilized body protein, may indicate that the dietary supply of amino acids was

inadequate and suggests ewes may possibly have responded to protein supplementation. This is an area worthy of further work in the lactating ewe at pasture.

The variation found in $K_{1(t)}$ in the present experiments, particularly in relation to changes in body energy mobilization, or body weight loss, highlight the need for adjustments in calculation of ME requirements of the ewe during early lactation, according to body energy or body weight change. Furthermore, the 10-15% greater intake of ME, compared with calculated requirements using ARC (1980) recommendations, demonstrates the need for revision of theoretical energy requirements for lactating ewes at pasture.

ACKNOWLEDGEMENTS

REFERENCES

ARC 1965. "The Nutrient Requirements of Farm Livestock, No. 2, Ruminants". Agricultural Research Council. CAB, London

ARC 1980. "The Nutrient Requirements of Ruminant Livestock". Agricultural Research Council Working party. CAB, London.

AOAC 1960. "Methods of Analysis" Tenth edition, Association of Official Agricultural Chemists, Washington, D.C.

ARMSTRONG, D.G. 1968. The amount and physical form of feed and milk secretion in the cow. Proceedings of the Nutrition Society 27: 57-65.

ARNOLD, G.W. 1964. Factors within plant associations affecting the behaviour and performance of grazing animals. In "Grazing Terestrial and Marine Environments". Ed. D.J. Chrisp. Blackwells, Oxford. pp. 133-154

ARNOLD, G.W. 1975. Herbage intake and grazing behaviour in ewes of four breeds at different physiological states. Australian Journal of Agricultural Research 26: 1017-1024.

ARNOLD, G.W.; McMANUS, W.R.; BUSCH, I.G.; BALL, J. 1964. The use of sheep fitted with oesophageal fistulas to measure diet quality. Australian Journal of Experimental Agriculture and Animal Husbandry 4: 71-79.

ARNOLD, G.W.; DUDZINSKI, M.L. 1967. Studies on the diet of the grazing animal. II. The effect of physiological status in ewes and pasture availability on herbage intake. Australian Journal of Agricultural Research 18: 349-359.

BAILE, C.A.; FORBES, J.M. 1974. Control of feed intake and energy balance in ruminants. Physiological Reviews 54: 160-214.

BALCH, C.C.; CAMPLING, R.C. 1962. Regulation of voluntary food intake in ruminants. Nutrition Abstracts and Reviews 32: 669-686.

BALDWIN, R.L.; KOONG, L.J.; ULYATT, M.J. 1977. A dynamic model of ruminant digestion for evaluation of factors affecting nutritive value. Agricultural Systems 2: 255-288.

BARNICOAT, C.R.; LOGAN, A.G.; GRANT, A.I. 1949. Milk secretion studies with New Zealand Romney ewes. Journal of Agricultural Science, Cambridge 39: 44-55.

BAROWICZ, T. 1979. Inhibitory effect of adrenalin on oxytocin release in the ewe during the milk-ejection reflex. Journal of Dairy Research 46: 41-46.

BARRY, T.N. 1980. Responses to abomasal infusions of casein plus methionine in lactating ewes fed fresh pasture. N.Z. Journal of Agricultural Research 23: 427-431.

BENJAMIN, R.W.; CHEN, M.; DEGEN, A.A.; ABDUL AZIZ, N.; AL HADAD, M.J. 1977. Estimation of the dry- and organic-matter intake of young sheep grazing a dry Mediterranean pasture, and their maintenance requirements. Journal of Agricultural Science, Cambridge 88: 513-520.

BINES, J.A.; SUZUKI, S.; BALCH, C.C. 1969. The quantitative significance of long-term regulation of food intake in the cow. British Journal of Nutrition 23: 695-704.

BLAXTER, 1957. The effects of defective nutrition during pregnancy in farm livestock. Proceedings of the Nutrition Society 16: 52-58.

BLAXTER, K.L. 1962. "The Energy Metabolism of Ruminants". Hutchinson, London.

BLAXTER, K.L. 1969. In "Energy metabolism of farm animals : 4th symposium". Warsaw, 1967 (EAAP). Eds. K.L. Blaxter, J. Kielanowski and G. Torbeck. Oriel Press, Newcastle-upon-Tyne. p.21.

BLAXTER, K.L.; CLAPERON, J.L.; WAINMAN, F.W. 1966. The extent of differences between six british breeds of sheep in their metabolism, feed intake and utilization, and resistance to climatic stress. British Journal of Nutrition 20: 283-294.

BOYAZOGLU, J.G. 1963. Aspects quantitatifs de la production latiere des brebis. Annales de Zootechnie 12: 237-296.

BRAITHWAITE, G.D.; GLASCOCK, R.F.; RIAZUDDIN, S. 1969. Calcium metabolism in lactating ewes. British Journal of Nutrition 23: 827-834.

BRETT, D.J.; CORBETT, J.L.; INSKIP, M.W. 1972. Estimation of the energy value of ewe milk. Proceedings of the Australian Society of Animal Production 9: 286-291.

BRODY, S. 1945. In "Bioenergetics and Growth", Reinhold, New York.

BROWN, L.D. 1966. Influence of intake on feed utilization. Journal of Dairy Science 49: 223-230.

BURTON, J.H.; ANDERSON, M.; REID, J.T. 1974. Some biological aspects of partial starvation. The effect of weight loss and regrowth on body composion in sheep. British Journal of Nutrition 32: 515-527.

BUTTERWORTH, M.H. 1965. Some aspects of the utilization of tropical forages. I. Green Elephant grass at various stages of growth. Journal of Agricultural Science, Cambridge 65: 233-239.

CAMPBELL, A.G. 1969. Grazing interval, stocking rate, and pasture production. N.Z. Journal of Agricultural Research 12: 67-74.

CAMPBELL, A.G.; PHILLIPS, D.S.M.; O'REILLY, E.D. 1962. Journal of the British Grassland Society 17: 89.

CAMPBELL, ROSA M.; FELL, B.F. 1970. Observations on hypertrophy of the liver in breeding ewes. Research and Veterinary Science 11: 540-547.

CARROLL, E.J.; JACOBSEN, M.S.; KASSOUNY, M.; SMITH, N.E.; ARMSTRONG, D.T. 1968. Inhibitory effect of oxytocin on the milk ejection reflex. Endocrinology 82: 179-182.

COOK, C.W. 1964. Symposium on nutrition of forages and pastures: Collecting forage samples representative of ingested material of grazing animals for nutritional studies. Journal of Animal Science 23: 265-270.

COOK, C.W.; STODDARD, L.A.; HARRIS, L.E. 1952. Determining the digestibility and metabolizable energy of winter range plants by sheep. Journal of Animal Science 11: 578-590.

COOMBE, J.B.; WARDROP, I.D.; TRIBE, D.E. 1960. A study of milk production of the grazing ewe, with emphasis on the experimental technique employed. Journal of Agricultural Science, Cambridge 54: 353-359.

COOP, I.E. 1962. The energy requirements of sheep for maintenance and gain. I. Pen fed sheep. Journal of Agricultural Science, Cambridge 58: 179-186.

COOP, I.E.; HILL, M.K. 1962. The energy requirements of sheep for maintenance and gain. II. Grazing sheep. Journal of Agricultural Science, Cambridge 58: 187-199.

COOP, I.E.; DREW, K.R. 1963. Maintenance and lactation requirements of grazing sheep. Proceedings of the N.Z. Society of Animal Production 23: 53-62.

COOP, I.E.; CLARK, V.R.; CLARO, D. 1972. Nutrition of the ewe in early lactation. 1 Lamb growth rate. N.Z. Journal of Agricultural Research 15: 203-208.

COOP, I.E.; ABRAHAMSON, M. 1973. Effect of teeth condition on intake of grazing sheep. N.Z Journal of Experimental Agriculture 1: 58-64.

COPPOCK, C.E.; TYRRELL, H.F.; MERRILL, W.G.; REID, J.T. 1968. The significance of protein reserve to the lactating cow. Proceedings of the Cornell Nutrition Conference for Feed Manufacturers. pp. 86-94.

CORBETT, J.L. 1960. Faecal-index techniques for estimating herbage consumption by grazing animals. Proceedings of the International Grassland Congress, 8: 438-442.

CORBETT, J.L. 1968. Variation in the yield and composition of milk of grazing Merino ewes. Australian Journal of Agricultural Research 19: 283-294.

CORBETT, J.L. 1978. Measuring animal performance. In "Measurement of grassland vegetation and animal production". Ed. L. t'Mannetje. Bulletin 5, CAB. pp. 163-231.

CORBETT, J.L.; GREENHALGH, J.F.D.; MCDONALD, I.; FLORENCE, E. 1960. Excretion of chromium sesquioxide administered as a component of paper to sheep. British Journal of Nutrition 14: 289-299.

COWAN, R.T.; ROBINSON, J.J.; GREENHALGH, J.F.D.; MCHATTIE, I. 1979. Body composition changes in lactating ewes estimated by serial slaughter and deuterium dilution. Animal Production 29: 81-90.

COWAN, R.T.; ROBINSON, J.J.; MCDONALD, I.; SMART, R. 1980a. Effects of body fatness at lambing and diet in lactation on body tissue loss, feed intake and milk yield of ewes in early lactation. Journal of Agricultural Science, Cambridge 95: 497-514.

COWAN, R.T.; ROBINSON, J.J.; MCHATTIE, I.; FRASER, C. 1980b. The prediction of body composition in live ewes in early lactation from live weight and estimates of gut contents and total body water. Journal of Agricultural Science, Cambridge 95: 515-522.

COWAN, R.T.; ROBINSON, J.J.; MCHATTIE, I.; PENNIE, K. 1981. Effects of protein concentration in the diet on milk yield, change in body composition and the energy utilization of body tissue for milk production in ewes. Animal Production 33: 111-120

COWIE, A.T.; FOLLEY, S.J.; CROSS, B.A.; HARRIS, G.W.; JACOBSOHN, D.; RICHARDSON, K.C. 1951. Terminology for use in lactational physiology.

Nature, London 168: 421.

CRABTREE, J.R. 1967. The effect of age and previous nutrition on the voluntary feed intake of roughage-concentrate diets by sheep (abstract). Animal Production 9: 275.

CROKER, B.H. 1959. A method of estimating the botanical composition of the diet of sheep. N.Z. Journal of Agricultural Research 2: 72-85.

DAVENPORT, D.G.; RAKES, A.H. 1969. Effects of prepartum feeding level and body condition on postpartum performance of dairy cows. Journal of Dairy Science 52: 1037-1043.

DAVISON, J. 1959. Experiences in the measurement of herbage consumption by livestock. In "The measurement of grassland productivity". Proceedings of the sixth Easter School in Agricultural Science, University of Nottingham. Ed. J.D. Ivins. London, Butterworth. pp. 79-87.

DENAMUR, R. 1965. The hypothalamo-neurohypophysial system and milk ejection reflex. Dairy Science Abstracts 27: 193-224, 263-280.

DENAMUR, R.; MARTINET, J. 1961. Action de l'oxytocine sur la secretion du lait des brebis. Annales d'Endocrinologie 22: 777-781.

DINIUS, D.A.; BAUMGARDT, B.R. 1970. Regulation of food intake in ruminants. 6 Influence of caloric density of pelleted rations. Journal of Dairy Science 53: 311-316.

DONEY, J.M.; RUSSEL, A.J.F. 1968. Differences amongst breeds of sheep in food requirements for maintenance and live weight change. Journal of Agricultural Science, Cambridge 71: 343-349.

DONEY, J.M.; PEART, J.N.; SMITH, W.F.; LOUDA, F. 1979. A consideration of the techniques for estimation of milk yield by suckled sheep and a comparison of estimates obtained by two methods in relation to the effect of breed, level of production and stage of lactation. Journal of Agricultural Science, Cambridge 92: 123-132.

DONEY, J.M.; GUNN, R.G.; PEART, J.N.; SMITH, W.F. 1981. Effect of body condition and pasture type on herbage intake, performance during lactation and subsequent ovulation rate in Scottish Blackface ewes. Animal Production 33: 241-247.

DONNELLY, J.R.; FREER, M. 1974. Prediction of body composition in live sheep. Australian Journal of Agricultural Research 25: 825-834.

DONNELLY J.R.; DAVISON, J.L.; FREER, M. 1974. Effect of body condition on the intake of food by mature sheep. Australian Journal of Agricultural Research 25: 813-823.

DREW, K.R.; REID, J.T. 1975. Compensatory growth in immature sheep. I. The effects of weight loss and realimentation on the whole body composition. Journal of Agricultural Science, Cambridge 85: 193-204.

ELLIS, W.C. 1968. Dysprosium as an indigestible marker and its determination by radioactivation analysis. Journal of Agricultural and Food Chemistry 16: 220-224.

EVERITT, G.C. 1966. Maternal food consumption and foetal growth of Merino sheep. Proceedings of the Australian Society of Animal Production 6: 91-101.

FELL, B.F.; CAMPBELL, R.M.; MACKIE, W.S.; WEEKES, T.E.C. 1972. Changes associated with pregnancy and lactation in some extra-reproductive organs of the ewe. Journal of Agricultural Science, Cambridge 79: 397-407.

FIELD, A.C.; SUTTLE, N.F.; GUNN, R.G. 1968. Seasonal changes in the composition and mineral content of the body of hill ewes. Journal of Agricultural Science, Cambridge 71: 303-310.

FLATT, W.P.; MOE, P.W.; VAN ES, A.J.H. 1968. Proceedings of the second World Conference on Animal Production. p. 399.

FLATT, W.P.; MOE, P.W.; MOORE, L.A.; BREIREM, K.; EKERN, A. 1972. Cited by ARC (1980).

FLETCHER, J.E.; ROBINSON, M.E. 1956. A capacitance meter for estimating forage weight. Journal of Range Management 9: 96-97.

FOLLEY, S.J. 1952. In "Marshall's Physiology of Reproduction", Ed. A.S. Parkes, 3rd edition. Longmans Green, London. p. 587.

FOOT, J.Z.; RUSSEL, A.J.F. 1979. The relationship in ewes between voluntary food intake during pregnancy and forage intake during lactation and after weaning. Animal Production 28: 25-39.

FORBES, J.M. 1968a. The water intake of ewes. British Journal of Nutrition 22: 33-43.

FORBES, J.M. 1968b. The physical relationships of the abdominal organs in the pregnant ewe. Journal of Agricultural Science, Cambridge 70: 171-177.

FORBES, J.M. 1968c. Cited by Forbes (1970).

FORBES, J.M. 1969a. The effect of pregnancy and fatness on the volume of rumen contents in the ewe. Journal of Agricultural Science, Cambridge 72. 119-121.

FORBES, J.M. 1969b. A note on the voluntary feed intake of lactating ewes, their milk yield and the growth rate of their lambs. Animal Production 11: 263-266.

FORBES, J.M. 1970. The voluntary feed intake of pregnant and lactating ruminants: a review. The British Veterinary Journal 126: 1-11.

FORBES, J.M. 1977. Interrelationships between physical and metabolic control of voluntary food intake in fattening, pregnant and lactating mature ewes: a model. Animal Production 24: 94-101.

FORBES, J.M. 1979. Hormones and metabolites in the control of food intake. In "Digestive Physiology and Metabolism in Ruminants" Editors Y. Ruckebush and P. Thivend. MTB Press Ltd., Lancaster, England. pp. 145-160.

GARDNER, R.W; HOGUE, D.E. 1964. Effects of energy intake and number of lambs suckled on milk yield, milk composition and energetic efficiency of lactating ewes. Journal of Animal Science 23: 935-942.

GARDNER, R.W.; HOGUE, D.E. 1966. Milk production, milk composition and energetic efficiency of Hampshire and Corriedale ewes fed to maintain body weight. Journal of Animal Science 25: 789-795.

GEENTY, K.G. 1975. The use of water turnover as a measure of voluntary intake in grazing sheep. Annual report of the Research Division, N.Z. Ministry of Agriculture and Fisheries. p. 209.

GEENTY, K.G. 1979. Lactation performance, growth and carcass composition of sheep. I. Milk production, milk composition, and live weights of Romney, Corriedale, Dorset, Romney X Dorset, and Dorset X Romney ewes in relation to the growth of their lambs. N.Z. Journal of Agricultural Research 22: 241-250.

GEENTY, K.G.; CLARKE, J.N.; JURY, K.E. 1979. Carcass growth and development of Romney, Corriedale, Dorset and crossbred sheep. N.Z. Journal of Agricultural Research 22: 23-52.

GEENTY, K.G. 1980. Dairy and suckled milk production of Dorset ewes. N.Z. Journal of Experimental Agriculture 8: 191-197.

GEENTY, K.G.; DAVISON, P.G. 1982. Influence of weaning age, milking frequency and udder stimulation on dairy milk production and post-partum oestrus interval of Dorset ewes. N.Z. Journal of Experimental Agriculture 10: 1-5.

GEENTY, K.G.; CLARKE, J.N.; WRIGHT, D.E. 1983. Lactation performance, growth and carcass composition of sheep. II. Relationships between milk yield, lamb water turnover and lamb growth in Romney, Dorset and crossbred sheep. In preparation.

GIBB, M.J.; TREACHER, T.T. 1978. The effect of herbage allowance on herbage intake and performance of ewes and their twin lambs grazing perenial ryegrass. Journal of Agricultural Science, Cambridge 90: 139-147.

GIBB, M.J.; TREACHER, T.T. 1980. The effect of ewe body condition at lambing on the performance of ewes and their lambs at pasture. Journal of Agricultural Science, Cambridge 95: 631-640.

GINGINS, M.; BICKEL, H.; SCHURCH, A. 1980. Efficiency of energy utilization in undernourished and realimented sheep. Livestock Production Science 7: 465-471.

GONZALEZ, J.S.; ROBINSON, J.J.; MCHATTIE, I.; FRASER, C. 1982. The effect in ewes of source and level of dietary protein on milk yield, and the relationship between the intestinal supply of non-ammonia nitrogen and the production of milk protein. Animal Production 34: 31-40.

GORDON, J.G.; TRIBE, D.E. 1951. The self-selection of diet by pregnant ewes. Journal of Agricultural Science, Cambridge 7: 465-471.

GRAHAM, N.McC. 1964. Energy exchanges of pregnant and lactating ewes. Australian Journal of Agricultural Research 15: 127-141.

GRAHAM, N.MCC. 1969. The influence of body weight (fatness) on the energetic efficiency of adult sheep. Australian Journal of Agricultural Research 20: 375-385.

GRAHAM, N.MCC.; WILLIAMS, A.J. 1962. The effects of pregnancy on the passage of food through the digestive tract of sheep. Australian Journal of Agricultural Research 13: 894-900.

GRAHAM, N.MCC.; SEARLE, T.W.; GRIFFITHS, D.A. 1974. Basal metabolic rate in lambs and young sheep. Australian Journal of Agricultural Research 25: 957-971.

GREEN, J.O. 1949. Herbage sampling errors and grazing trials. Journal of the British Grassland Society 4: 11-16.

GREEN, J.O.; LANGER, H.J.; WILLIAMS, T.E. 1952. Sources and magnitude of experimental errors in grazing trials. Proceedings of the sixth International Grassland Congress. pp. 1374-1379.

GREENHALGH, J.F.D.; CORBETT, J.L. 1960. The indirect estimation of the digestibility of pasture herbage. I. Nitrogen and chromogen as faecal index substances. Journal of Agricultural Science, Cambridge 55: 371-376.

GREENHALGH, J.F.D.; CORBETT, J.L.; MCDONALD, I. 1960. The indirect estimation of the digestibility of pasture herbage. II. Regressions of digestibility on faecal nitrogen concentration; their determination in continuous digestibility trials and the effect of various factors on their accuracy. Journal of Agricultural Science, Cambridge 55: 377-386.

GREENHALGH, J.F.D; REID, G.W.; MCDONALD, I. 1966. The indirect estimation of the digestibility of pasture herbage. IV. Regressions of digestibility on faecal nitrogen concentration; effects of different fractions of the herbage upon within- and between-period regressions. Journal of Agricultural Science, Cambridge 66: 277-283.

HADJIPIERIS, G.; HOLMES, W. 1966. Studies on feed intake and feed utilization by sheep. I The voluntary feed intake of dry, pregnant and lactating ewes. Journal of Agricultural Science, Cambridge 66: 217-223.

HADJIPIERIS, G.; JONES, J.G.W.; WIMBLE, R.H.; HOLMES, W. 1966. Studies on feed intake and feed utilization by sheep. II The utilization of feed by ewes. Journal of Agricultural Science, Cambridge 66: 341-349.

HALL, D.G.; HAMILTON, B.A. 1975. Estimation of the botanical composition of oesophageal extrusa samples. 2. A comparison of manual separation and a microscope point technique. Journal of the British Grassland Society 30: 273-277.

HAMILTON, B.A.; HUTCHINSON, K.J.; ANNIS, P.C.; DONNELLY, J.B. 1973. Relationships between the diet selected by grazing sheep and the herbage on offer. Australian Journal of Agricultural Research 24: 271-277.

HEADY, H.F.; TORRELL, D.T. 1959. Forage preference exhibited by sheep with oesophageal fistulas. Journal of Range Management 12: 28-34.

HEANEY, D.P.; PRITCHARD, G.I.; PIGDEN, W.J. 1968. Variability in ad-libitum forage intakes by sheep. Journal of Animal Science 27: 159-164.

HEANEY, D.P.; LODGE G.A. 1975. Body composition and energy metabolism during late pregnancy in the ad-libitum fed ewe. Canadian Journal of Animal Science 55: 545-555.

HERCUS, B.H. 1960. Plant cuticle as an aid to determining the diet of grazing animals. Proceedings of the VIIIth Grassland Congress. pp. 443-447.

HIGHT, G.K.; BARTON, R.A. 1965. The effects of undernutrition and realimentation on the Romney ewe. Journal of Agricultural Science, Cambridge 64: 413-424.

HODGE, R.W.; DOYLE, J.J. 1967. Diet selected by lambs and yearling sheep grazing on annual and perennial pastures in southern Victoria. Australian Journal of Experimental Agriculture and Animal Husbandry 7: 141-143.

HODGSON, J. 1977. Factors limiting herbage intake by the grazing animal. In "Proceedings of the International Meeting on Animal Production from Temperate Grasslands." Dublin. pp. 70-75.

HOEHNE, O.E.; CLANTON, D.C.; STREETER, C.L. 1967. Chemical changes in oesophageal fistula samples caused by salivery contamination and sample preparation. Journal of Animal Science 26: 628-631.

HOFFMAN, L.; SCHIEMANN, R.; JENTSCH, W.; HENSELER, G. 1974. Cited by ARC (1980).

HOGLUND, J.H.; BROCK, J.L. 1978. Regulation of nitrogen fixation in a grazed pasture. N.Z. Journal of Agricultural Research 21: 73-82.

HUGHES, J.G. 1976. Short-term variation in animal live weight and reduction of its effect on weighing. Animal Breeding Abstracts 44: 111-118.

HUGHES, T.P.; POPPI, D.; SYKES, A.R. 1980. Some implications of sward chemical and physical characteristics for the nutrition of grazing ruminants. Proceeedings of the N. Z. Society of Animal Production 40: 68-84.

HUSTON, J.E.; ELLIS, W.C. 1968. Evaluation of certain properties of radiocerium as an indigestible marker. Journal of Agricultural and Food Chemistry 16: 225-230.

HUTTON, J.B.; PARKER, O.F. 1963. The significance of differences in levels of feeding before and after calving, and milk yield under intensive grazing. N.Z.Journal of Agricultural Research 16: 95-104.

HUTTON, J.B.; 1963. The effect of lactation on intake in the dairy cow. Proceedings of the N.Z. Society of Animal Production 23: 39-52.

INGLETON, J.W. 1971. Faeces collection in young male lambs and wether sheep. Journal of the British Grassland Society 26: 103-106.

IWTO 1976. Determination of wool base, vegetable matter base, "IWTO clean wool content" and "IWTO scoured yield" in raw wool. International Wool Textile Organization-19-76(E).

JAGUSCH, K.T.; COOP, I.E. 1971. The nutritional requirements of grazing sheep. Proceedings of the N.Z. Society of Animal Production 31: 224-234.

JAGUSCH, K.T.; MITCHELL, R.M. 1971. Utilisation of the metabolisable energy of ewe's milk by the lamb. N.Z. Journal of Agricultural Research 14: 434-441.

JAGUSCH, K.T.; JAY, N.P.; CLARK, V.R. 1972. Nutrition of the ewe in early lactation. II Milk yield. N.Z. Journal of Agricultural Research 15 209-213.

JOYCE, J.P.; BLAXTER, K.L. 1964. The effect of air movement, air temperature and infrared radiation on the energy requirements of sheep. British Journal of Nutrition 18: 5-27.

JONES, R.J.; HAYDOCK, K.P. 1970. Yield estimation of tropical and temperate pasture species using an electronic capacitance meter. Journal of Agricultural Science, Cambridge 75: 27-36.

JONES, D.I.H.; HAYWARD, M.V. 1975. The effect of pepsin pretreatment of herbage on the prediction of dry matter digestibility from solubility in fungal cellulase solutions. Journal of Science and Food Agriculture 26: 711-718.

KEENAN, D.M., MCMANUS, W.R.; FREER, M. 1969. Changes in the body composition and efficiency of mature sheep during loss and regain of live weight. Journal of Agricultural Science, Cambridge 72: 139-147.

KENNEDY, W.K.; CARTER, A.H.; LANCASTER, R.J. 1959. Comparison of faecal pigments and faecal nitrogen as digestibility indicators in grazing cattle studies. N.Z. Journal of Agricultural Research 2: 627-638.

KEYS, J.E.; VAN SOEST, P.J.; YOUNG, E.P. 1969. Comparative study of the digestibility of forage cellulose and hemicellulose in ruminants and non-ruminants. Journal of Animal Science 29: 11-15.

KLEIBER, MAX; REGAN, W.M.; MEAD, S.W. 1945. Measuring food values for dairy cows. Hilgardia 19(11): 511-572.

KOTB, A.R.; LUCKEY, T.D. 1972. Markers in nutrition. Nutrition Abstracts and Reviews 42: 813-845.

LABUSSIERE, J.; MARTINET, J.; DENAMUR, R. 1969. The influence of the milk ejection reflex on the flow rate during the milking of ewes. Journal of Dairy Research 36: 191-201.

LAMBOURNE, L.J.; REARDON, T.F. 1963. The use of chromium oxide to estimate the faecal output of Merinos. Australian Journal of Agricultural Research 14: 239-256.

LANCASTER, R.J. 1949. Estimation of digestibility of grazed pasture from faeces nitrogen. Nature, London 163: 330-331.

LANGLANDS, J.P.; CORBETT, J.L.; MCDONALD, I.; REID, G.W. 1963a. Estimation of the faeces output of grazing animals from the concentration of chromium sesquioxide in a sample of faeces. I. Comparison of estimates from samples taken at fixed times of day with faeces outputs measured directly. British Journal of Nutrition 17: 211-218.

LANGLANDS, J.P.; CORBETT, J.L.; MCDONALD, I.; REID, G.W. 1963b. Estimation of the faeces output of grazing animals from the concentration of chromium sesquioxide in a sample of faeces. 2. Comparison of estimates from samples taken at fixed times of day with estimates from samples collected from the sward. British Journal of Nutrition 17: 219-226.

LANGLANDS, J.P.; CORBETT, J.L.; MCDONALD, I. 1963c. The indirect estimation of the digestibility of pasture herbage. III. Regressions of digestibility on faecal nitrogen concentration: effects of species and individuality of animal and of the method of determining digestibility upon the relationship. Journal of Agricultural Science, Cambridge 61: 221-226.

LANGLANDS, J.P. 1966. Studies on the nutritive value of the diet selected by grazing sheep. I Differences in composition between herbage consumed and material collected from oesophageal fistulae. Animal Production 8: 253-259.

LANGLANDS, J.P. 1967a. Studies on the nutritive value of the diet selected by grazing sheep. II Some sources of error when sampling oesophageally fistulated sheep at pasture. Animal Production 9: 167-175.

LANGLANDS, J.P. 1967b. Studies on the nutritive value of the diet selected by grazing sheep. III. A comparison of oesophageal fistula and faecal index techniques for the indirect estimation of digestibility. Animal Production 9: 325-331.

LANGLANDS, J.P. 1969a. Studies on the nutritive value of the diet selected by grazing sheep. IV. Variation in the diet selected by sheep differing in age, breed, sex, strain and previous history. Animal Production 11: 369-378.

LANGLANDS, J.P. 1969b. Studies on the nutritive value of the diet selected by grazing sheep. V. Further studies of the relationship between digestibility estimated in-vitro from oesophageal fistula samples and from faecal and dietary composition. Animal Production 11: 379-387.

LANGLANDS, J.P. 1973. Milk and herbage intakes by grazing lambs born to Merino ewes and sired by Merino, Border Leicester, Corriedale, Dorset Horn and Southdown rams. Animal Production 16: 285-291.

LANGLANDS, J.P.; BENNETT, I.L. 1973. Stocking intensity and pastoral production. III. Wool production, fleece characteristics, and the utilization of nutrients for maintenance and wool growth by Merino sheep grazed at different stocking rates. Journal of Agricultural Science, Cambridge 81: 211-218.

LANGLANDS, J.P.; BOWLES, J.E. 1973. Studies on the nutritive value of the diet selected by grazing sheep. VI. The use of tritiated water as a marker to estimate the composition of the diet from material collected by oesophageally fistulated sheep. Animal Production 16: 59-65.

LANGLANDS, J.P. 1974. Studies on the nutritive value of the diet selected by grazing sheep. VII. A note on hand plucking as a technique for estimating dietary composition. Animal Production 19: 249-252.

LANGLANDS, J.P. 1975. Techniques for estimating nutrient intake and its utilization by the grazing ruminant. In "Digestion and Metabolism in the Ruminant". Eds. I.W. McDonald and A.C.I. Warner. University of New England, Armidale, Australia.

LANGLANDS, J.P. 1977. The intake and production of lactating Merino ewes and their lambs grazed at different stocking rates. Australian Journal of Agricultural Research 28: 133-142.

LEYVA, V.; HENDERSON, A.E.; SYKES, A.R. 1981. The effect of daily infection with O. circumcincta larvae on the performance of pregnant and lactating sheep. Proceedings of the N.Z. Society of Animal Production 41: 279-282.

LINEHAN, P.A. 1952. Use of cage and mower-strip methods for measuring the forage consumed by grazing animals. Proceedings of the sixth International Grasslands Congress. pp. 1328-1333.

LINZELL, J.L. 1972. Milk yield, energy loss in milk, and mammary gland weight in different species. Dairy Science Abstracts 34: 351-360.

LISTER, D. 1976. Effects of nutrition and genetics on composition of the body. Proceedings of the Nutrition Society 35: 351-356.

LITTLE, D.A.; SANDLAND, R.L. 1975. Studies on the distribution of the body fat in sheep during continuous growth, and following nutritional restriction and rehabilitation. Australian Journal of Agricultural Research 26: 363-374.

LOCKHART, L.W. 1954. Sampling of fleeces for yield, staple length, and crimps per inch measurement. Australian Journal of Agricultural Research 5: 555-567.

LODGE, G.A.; HEANEY, D.P. 1973. Composition of weight change in the pregnant ewe. Canadian Journal of Animal Science 53: 95-105.

LODGE, G.A.; FISHER, L.J.; LESSARD, J.R. 1975. Influence of prepartum feed intake on performance of cows fed ad-libitum during lactation. Journal of Dairy Science 58: 696-702.

LOFFGREEN, G.P.; GARRETT, W.N. 1968. A system for expressing net energy requirements and feed values for growing and finishing beef cattle. Journal of Animal Science 27: 793.

LOWE, J. 1959. A review of herbage production and consumption yield measurement techniques adopted in Northern Ireland. In "The measurement of grassland productivity". Proceedings of the sixth Easter School in Agricultural Science. University of Nottingham. Butterworths, London. Ed. I.D. Ivins. pp. 88-103.

MACFARLANE, W.V.; HOWARD, B.; SIEBERT, B.D. 1969. Tritiated water in the measurement of milk intake and tissue growth of ruminants in the field. Nature, London 221: 578-579.

MACFARLANE, W.V.; HOWARD, B.; GOOD, B.F. 1972. Use of tracers in field measurements of water, milk and thyroxine metabolism of tropical ruminants. Mimeograph 5064. Waite Agricultural Research Institute, Glen Osmond, South Australia.

MCCANCE, I. 1959. The determination of milk yield in the Merino ewe. *Australian Journal of Agricultural Research* 10: 839-853.

MCMANUS, W.R.; ARNOLD, G.W.; HAMILTON, F.J. 1962. Improved techniques in oesophageal fistulation of sheep. *Australian Veterinary Journal* 38: 275-281.

MCQUEEN, R.; VAN SOEST, P.J. 1975. Fungal cellulase and hemicellulase prediction of forage digestibility. *Journal of Dairy Science* 58: 1482-1491.

MAXWELL, T.J.; DONEY, J.M.; MILNE, J.A.; PEART, J.N.; RUSSEL, A.J.F.; SIBBALD, A.R.; MCDONALD, D. 1979. The effect of rearing type and pre-partum nutrition on the intake and performance of lactating Greyface ewes at pasture. *Journal of Agricultural Science, Cambridge* 92: 165-174.

MILNE, J.A.; MAXWELL, T.J.; SOUTER, W. 1981. Effect of supplementary feeding and herbage mass on the intake and performance of grazing ewes in early lactation. *Animal Production* 32: 185-195.

MINSON, D.J.; TAYLOR, J.C.; ALDER, F.E.; RAYMOND, W.F.; RUDMAN, J.E.; LINE, C.; HEAD, M.J. 1960. A method for identifying the faeces produced by individual cattle or groups of cattle grazing together. *Journal of the British Grassland Society* 15: 86-88.

MOE, P.W.; FLATT, W.P. 1969. Use of body tissue reserves for milk production by the dairy cow. (Abstract) *Journal of Dairy Science* 52: 928.

MOE, P.W.; TYRRELL, H.F.; FLATT, W.P. 1971. Energetics of body tissue mobilisation. *Journal of Dairy Science* 54: 548-553.

MOE, P.W.; TYRRELL, H.F. 1975. Symposium: Production efficiency in the high producing cow. Efficiency of conversion of digested energy to milk. *Journal of Dairy Science* 58: 602-610.

MOORE, R.W. 1962. Comparison of two techniques for the estimation of the milk intake of lambs at pasture. Proceedings of the Australian Society of Animal Production 4: 66-68.

MORAG, M. 1968. A galactopoeitic effect from oxytocin administered between milkings in the cow. Annales de Biologie Animale Biochimie Biophysique 8: 27-43.

MORAG, M. 1969. The relation between the passage of time and the secretion of milk in the ewe. Australian Journal of Agricultural Research 20: 941-951.

MORAG, M.; FOX, S. 1966. Galactokinetic responses to oxytocin in the ewe. Annales de Biologie Animals Biochimie Biophysoique 6: 467-478.

MOULTON, C.E. 1923. Age and chemical development in mammals. Journal of Biological Chemistry 57: 79-97.

OH, H.K.; BAUMGARDT, B.R.; SCHOLL, J.M. 1966. Evaluation of forages in the laboratory. V. Comparison of chemical analysis, solubility tests, and in-vitro fermentation. Journal of Dairy Science 49: 850-855.

ORSKOV, E.R.; MCDONALD, I.; GRUBB, D.A.; PENNIE, K. 1976. The nutrition of the early weaned lamb. IV. Effects of growth rate, food utilization and body composition of changing from a low to a high protein diet. Journal of Agricultural Science, Cambridge 86: 411-423.

OWEN, J.B. 1957. A study of the lactation and growth of hill sheep in their native environment and under lowland conditions. Journal of Agricultural Science, Cambridge 48: 387-412.

PANARETTO, B.A. 1963. Body composition in-vivo. III. The composition of living ruminants and its relation to the tritiated water space. Australian Journal of Agricultural Research 14: 944-952.

PEART, J.N. 1967. The effect of different levels of nutrition during late pregnancy on the subsequent milk production of Blackface ewes and on the growth of their lambs. Journal of Agricultural Science, Cambridge 68: 365-371.

PEART, J.N. 1968. Some effects of live weight and body condition on the milk production of Blackface ewes. Journal of Agricultural Science, Cambridge 70: 331-338.

PEART, J.N. 1970. The influence of live weight and body condition on the subsequent milk production of Blackface ewes following a period of undernourishment in early lactation. Journal of Agricultural Science, Cambridge 75: 459-469.

PEART, J.N.; EDWARDS, R.A.; DONALDSON, ELIZABETH 1972. The yield and composition of the milk of Finnish Landrace X Blackface ewes. I. Ewes and lambs maintained indoors. Journal of Agricultural Science, Cambridge 79: 303-313.

PEART, J.N.; EDWARDS, R.A.; DONALDSON, E. 1975. The yield and composition of the milk of Finnish Landrace X Blackface ewes. II. Ewes and lambs grazed on pasture. Journal of Agricultural Science, Cambridge 85: 315-324.

PENNING, P.D.; GIBB, M.J. 1979. The effect of milk intake on the intake of cut and grazed herbage by lambs. Animal Production 29: 53-67.

RATTRAY, P.V.; GARRETT, W.N.; EAST, N.E.; HINMAN, N. 1973. Net energy requirements of ewe lambs for maintenance, gain and pregnancy and the net energy values of feedstuffs for lambs. Journal of Animal Science 37: 853-857.

RATTRAY, P.V.; GARRET, W.N.; EAST, N.E.; HINMAN, N. 1974a. Efficiency of utilization of metabolizable energy during pregnancy and the energy requirements for pregnancy in sheep. Journal of Animal Science 38: 383-393.

RATTRAY, P.V.; GARRETT, W.N.; HINMAN, N.; EAST, N.E. 1974b. Effects of level of nutrition, pregnancy and age on the composition of the wool-free ingesta-free body and carcass of sheep. Journal of Animal Science 39: 687-693.

RATTRAY, P.V.; GARRETT, W.N.; EAST, N.E. 1974c. Growth development and composition of the ovine conceptus and mammary gland during pregnancy. Journal of Animal Science 38: 613-626.

RATTRAY, P.V.; JAGUSCH, K.T. 1978. Pasture allowances for the breeding ewe. Proceedings of the N.Z. Society of Animal Production 38: 121-126.

RATTRAY, P.V.; TRIGG, T.E. 1979. Minimal feeding of pregnant ewes. Proceedings of the N.Z. Society of Animal Production 39: 242-250.

RATTRAY, P.V.; TRIGG, T.E.; URLICH, C.F; 1980. Energy exchanges in twin pregnant ewes. In "Energy metabolism". Proceedings of the eighth synposium on energy metabolism. Church College, Cambridge. September, 1979. Ed. Lawrence E. Mount. Butterworths, London. pp. 325-328.

RAYMOND, W.F. 1948. Evaluation of herbage for grazing. Nature, U.K., 161: 937-938.

RAYMOND, W.F.; HARRIS, C.E.; HARKER, V.G. 1953. Studies on the digestibility of herbage. I. Technique of measurement of digestibility and some observations on factors affecting the accuracy of digestibility data. Journal of the British Grassland Society 8: 301-314.

RAYMOND, W.F.; KEMP, C.D.; KEMP, A.W.; HARRIS, C.E. 1954. Studies on the digestibility of herbage. IV. The use of faecal collection and chemical analysis in pasture studies (b) Faecal index methods. Journal of the British Grassland Society 9: 69-79.

RAYMOND, W.F.; MINSON, D.J. 1955. The use of chromic oxide for estimating the faecal production of grazing animals. Journal of the British Grassland Society 10: 282-296.

RAYMOND, W.F.; MINSON, D.J.; HARRIS, C.E. 1956. The effect of management on herbage consumption and selective grazing. Proceedings of the VIIth International Grasslands Congress. pp. 123-133.

REID, J.T.; BESADOUN, A.; PALADINES, O.L.; VAN NIEKERK, B.D.H. 1963. Body water estimation in relation to body composition and indirect calorimetry in ruminants. Annals of the New York Academy of Science 110: 327-342.

REID, J.T.; BENSADOUN, A.; BULL, L.S.; BURTON, J.H.; GLEASON, P.A.; HAN, I.K.; JOO, Y.D.; JOHNSON, D.E.; MCMANUS, W.R.; PALADINES, O.L.; STROUND, J.W.; TYRRELL, H.F.; VAN NIEKERK, B.D.H.; WELLINGTON, G.W. 1968. In "Body Composition of Animals and Man". National Academy of Sciences, Washington D.C. Publication 1598. Ed. J.T. Reid.

RICKARD, D.S.; RADCLIFFE, J.E. 1976. Seasonal distribution of pasture production in New Zealand. XII. Winchmore, Canterbury Plains dryland and irrigated pastures. N.Z. Journal of Experimental Agriculture 4: 329-335.

ROBERTSON, J.B.; VAN SOEST, P.J. 1975. A note on digestibility in sheep as influenced by level of intake. Animal Production 21: 89-92.

ROBINSON, P. 1948. The effect of supermaintenance and submaintenance diets on mature Border Leicester-Cheviot ewes. Journal of Agricultural Science, Cambridge 38: 345-353.

ROBINSON, J.J. 1978. Response of the lactating ewe to variation in energy and protein intake. In "Milk production in the ewe". Proceedings of sessions of the Sheep and Goat Commission of the European Association of Animal Production. Brussels, August 1978. Publication 23. Eds. J.G. Boyazoglu and T.T. Treacher. pp. 53-63.

ROBINSON, J.J.; MCDONALD, I.; MCHATTIE, I.; PENNIE, K. 1978. Studies on reproduction in prolific ewes. 4. Sequential changes in the maternal body during pregnancy. Journal of Agricultural Science, Cambridge 91: 291-304.

ROBINSON, J.J.; MCHATTIE, I.; CALDERON CORTES, J.F.; THOMPSON, J.L. 1979. Further studies on the response of lactating ewes to dietary protein. Animal Production 29: 257-269.

ROBINSON, J.J.; MCDONALD, I.; FRASER, C.; GORDON, J.G. 1980. Studies on reproduction in prolific ewes. 6. The efficiency of energy utilization for conceptus growth. Journal of Agricultural Science, Cambridge 94: 331-338.

ROBINSON, J.J. 1982. Pregnancy. World Animal Science. C. Production-System Approach. 1 Sheep and Goat Production. Ed. I.E. Coop. Elsevier, Amsterdam. pp. 103-118.

ROWELL, J.G.; WALTERS, D.E. 1976. Analysing data with repeated observations on each experimental unit. Journal of Agricultural Science, Cambridge 87: 423-443.

ROY, J.H.B.; BALCH, C.C.; MILLER, E.L.; ORSKOV, E.R.; SMITH, R.H. 1977. Calculation of the N requirement for ruminants from nitrogen metabolism studies. In "Proceedings of the 2nd Symposium on Protein Metabolism and Nutrition". Centre for Agricultural Publishing and Documentation, Wagenin. pp. 126-129.

ROYAL, W.M. 1968. Equipment for collection of faeces from sheep. Proceedings of the Australian Society of Animal Production 7: 450-454.

RUBNER, M. 1888. Cited by ARC (1965).

RUSSEL, A.J.F.; DONEY, J.M.; REID, R.L. 1967. Energy requirements of the pregnant ewe. Journal of Agricultural Science, Cambridge 68: 359-363.

RUSSEL, A.J.F.; GUNN, R.G.; DONEY, J.M. 1968. Components of live weight loss in pregnant hill ewes during winter. Animal Production 10: 43-51.

RUSSEL, A.J.F.; DONEY, J.M.; GUNN, R.G. 1971. The distribution of chemical fat in the bodies of Scottish Blackface ewes. Animal Production 13: 503-509.

RUSSEL, A.J.F.; MAXWELL, T.J.; SIBBALD, A.R.; MCDONALD, D. 1977. Relationships between energy intake, nutritional state and lamb birth weight in Greyface ewes. Journal of Agricultural Science, Cambridge 89: 667-673.

SCHIEMANN, R.; JENTSCH, W.; WITTENBERG, H. 1971. Cited by ARC (1980).

SCHUTTE, J.A.; WILKE, P.I.; COMPAAN, J.P. 1971. Surgical procedure for the creation of an oesophageal fistual in sheep. Agroanimalia 3: 99-102.

SEARLE, T.W. 1970a. Body composition in lambs and young sheep and its prediction in-vivo from tritriated water space and body weight. Journal of Agricultural Science, Cambridge 74: 357-362.

SEARLE, T.W. 1970b. Prediction of body composition of sheep from tritiated water space and body weight - tests of published equations. Journal of Agricultural Science, Cambridge 75: 497-500.

SEARLE, T.W.; GRAHAM, N.MCC. 1975. Studies of weaner sheep during and after a period of weight stasis. II. Body composition. Australian Journal of Agricultural Research 26: 355-361.

SEARS, P.D.; GOODALL, V.C. 1942. Apparatus for the collection of urine and faeces from grazing sheep. N.Z. Journal of Science and Technology 23(A): 301-304.

SEEBECK, R.M. 1968. Developmental studies of body composition. Animal Breeding Abstracts 36: 167-181.

SIDAHMED, A.E.; MORRIS, J.G.; WEIR, W.C.; TORRELL, D.T. 1977. Effect of the length of fasting on intake, in-vitro digestibility and chemical composition of forage samples collected by esophageal fistulas in sheep. Journal of Animal Science, 46: 885-890.

SLATER, J.; JONES, R.J. 1971. Estimation of the diets selected by grazing animals from microscopic analysis of the faeces - a warning. Journal of the Australian Institute of Agricultural Science 37: 238-240.

SMITH, B.S.W.; SYKES, A.R. 1974. The effect of route of dosing and method of estimation of tritiated water space on the determination of total body water and the prediction of total body fat in sheep. Journal of Agricultural Science, Cambridge 82: 105-111.

STORR, G.M. 1961. Microscopic analysis of faeces, a technique for ascertaining the diet of herbivorous mammals. Australian Journal of Biology and Science 14: 157-164.

STERN, D.; ADLER, J.H.; TAGARI, H.; EYAL, E. 1978. Responses of dairy ewes before and after parturition to different nutritional regimes during pregnancy. II. Energy intake, body weight changes during lactation and milk production. Annales de Zootechnie 27: 335-346.

SYKES, A.R.; FIELD, A.C. 1972. Effects of dietary deficiencies of energy, protein and calcium on the pregnant ewe. 1. Body composition and mineral content of the ewe. Journal of Agricultural Science, Cambridge 78: 109-117.

SYKES, A.R. 1974. The prediction of the body composition of hill sheep from body weight, red cell volume and tritiated water space. Journal of Agricultural Science, Cambridge 82: 269-275.

SYKES, A.R.; FIELD, A.C.; GUNN, R.G. 1974. Effects of age and state of incisor dentition on body composition and lamb production of sheep grazing hill pastures. Journal of Agricultural Science, Cambridge 83: 135-143.

SYKES, A.R.; COOP, R.L. 1976. Intake and utilization of food by growing lambs with parasitic damage to the small intestine caused by daily dosing with Trichostrongylus colubriformis larvae. Journal of Agricultural Science, Cambridge 86: 507-515.

THOMPSON, P.D.; PAAPE, M.J.; SMITH, J.W. 1973. Residual milk yield as affected by dose and time of injection of oxytocin. Journal of Dairy Research 40: 221-227.

THOMSON, W.; THOMSON, A.M. 1953. Effect of diet on milk yield of the ewe and growth of her lamb. British Journal of Nutrition 7: 263-274.

THORNTON, R.F.; HOOD, R.L.; JONES, P.N.; RE, V.M. 1979. Compensatory growth in sheep. Australian Journal of Agricultural Research 30: 135-151.

TILLEY, J.M.A.; TERRY, R.A. 1963. A two-stage technique for the in-vitro digestion of forage crops. Journal of the British Grassland Society 18: 104-111.

TORRELL, D.T. 1954. An esophageal fistula for animal nutrition studies. Journal of Animal Science 13: 878-884.

TORRELL, D.T.; BREDON, R.M.; MARSHALL, B. 1967. Variation of esophageal fistula samples between animals and days on tropical grasslands. Journal of Range Manangement 20: 314-316.

TREACHER, T.T. 1970. Effects of nutrition in late pregnancy on subsequent milk production in ewes. Animal Production 12: 23-36.

TREACHER, T.T. 1971. Effects of nutrition in pregnancy and in lactation on milk yield in ewes. Animal Production 13: 493-501.

ULYATT, M.J.; BARTON, R.A. 1964. Effect of body composition and weight of ingesta on the number of lambs reared by Romeny Marsh ewes. Nature, London 202: 318-319.

ULYATT, M.J. 1971. Studies on the causes of the differences in pasture quality between perenial ryegrass, short-rotation ryegrass, and white clover. N.Z. Journal of Agricultural Research 14: 352-367.

ULYATT, M.J. 1972. Influence of experimental design in measuring the voluntary intake of grazing sheep. Proceedings of the N.Z. Society of Animal Production 32: 85-86.

ULYATT, M.J.; BLADWIN, R.L.; KOONG, L.J. 1976. The basis of nutritive value - a modeling approach. Proceedings of the N.Z. Society of Animal Production 36: 140-149.

VAN DYNE, G.M.; TORRELL, D.T. 1964. Development and use of the esophageal fistula: A review. Journal of Range Management 17: 7-19.

VAN SOEST, P.J. 1963. The use of detergents in the analysis of fibrous feeds. II. A rapid method for the determination of fiber and lignin. Journal of the Association of Official Agricultural Chemists 46: 829.

VAN SOEST, P.J.; WINE, R.H.; MOORE, L.A. 1966. Estimation of the true digestibility of forages by the in-vitro digestion of cell walls. In Proceedings of the 10th International Grasslands Congress. Helsinki. p. 438.

WAGNER, R.E. 1952. Weight estimation and other procedures for measuring the botanical composition of pastures. Proceedings of the sixth International Grasslands Congress. pp. 1315-1321.

WALLACE, L.R. 1948. The growth of lambs before and after birth in relation to the level of nutrition. Journal of Agricultural Science, Cambridge 38: 93-153.

WALTERS, R.J.K.; EVANS, E.M. 1979. Evaluation of a sward sampling technique for estimating herbage intake by grazing sheep. Grass and Forage Science 34: 37-44.

WEBSTER, A.J.F.; BROCKWAY, J.M.; SMITH, J.S. 1974. Prediction of the energy requirements for growth in beef cattle. 1. The irrelevance of fasting metabolism. Animal Production 19: 127-139.

WHITING, F.; SLEN, S.D.; BEZEAU, L.M. 1952. The quantity and quality of mature ewe's milk as influenced by level of protein in the ration. Scientific Agriculture 32: 365.

WILLIAMS, C.H.; DAVID, D.J.; IISMAA, O. 1962. The determination of chromic oxide in faeces samples by atomic absorbtion spectrophotometry. Journal of Agricultural Science, Cambridge 59: 381-385.

WODZICKA-TOMASZEWSKA, MANIKA 1963. The effect of shearing on the appetite of sheep. N.Z. Journal of Agricultural Research 6: 440-447.

WODZICKA-TOMASZEWSKA, MANIKA 1964. The effect of shearing on the appetite of ewes. N.Z. Journal of Agricultural Research 7: 654-662.

WRIGHT, D.E.; WOLFF, J.E. 1976. Measuring milk intake of lambs suckling grazing ewes by a double isotope method. Proceedings of the N.Z. Society of Animal Production 36: 99-102.

YATES, N.G.; MACFARLANE, W.V.; ELLIS, R. 1971. The estimation of milk intake and growth of beef calves in the field by using tritiated water. Australian Journal of Agricultural Research 22: 291-306.

YEATES, N.T.M.; EDEY, T.N.; HILL, M.K. 1975. "Animal Science : Reproduction, Climate, Meat, Wool." Pergamon Press, Sydney. p.341.

YOUNG, B.W.; CORBETT, J.L. 1972. Maintenance energy requirements of grazing sheep in relation to herbage availability. II. Observations on grazing intake. Australian Journal of Agricultural Research 23: 77-85.