# HAY QUALITY
# AND THE PREGNANT EWE

by

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1975

A dissertation submitted to
The University of Edinburgh
in fulfilment of the requirements
for the degree of Doctor of Philosophy.

## DECLARATION

I hereby declare that all the work presented in this thesis is my own, unless otherwise stated, and that the thesis has been composed by myself.

John A Ferguson

Contents

# ACKNOWLEDGMENTS

Acknowledgments

The author wishes to extend sincere thanks to Dr. W.J.M. Black of The Edinburgh School of Agriculture for his supervision and advice over the time of research for, and writing of this dissertation. Grateful acknowledgment is made to Professor F.W.H. Elsley (The Edinburgh School of Agriculture) who accepted the author for the chance of gaining a degree in his Department.

Mr. A. Cowe (Lowground Shepherd on the Farms of The Edinburgh School of Agriculture) is very sincerely thanked for his wisdom, care, guidance, hard work and general cheerfulness in the face of adversity, particularly when animals he cherished had periods of deprivation imposed upon them.

For assistance with data collection, acknowledgment is made of the tremendous efforts made by Mr. J. FitzSimons (Animal Recorder of The Edinburgh School of Agriculture) during the lambing periods. Mr. A. Donald is thanked for his work in the Metabolism Unit.

To Dr. G.K. Shukla and Mr. R. Thompson (A.R.C. Unit of Statistics) thanks are given for advice on experimental design and the easing of the load of statistical analysis of the data.

Many, notably Miss D.K. Wheeler B.Sc., Miss E. Warwick B.Sc., Miss M. Lyle, Mr. J.G.S. Duncan M.Phil; Mr. M. Hutcheson and Mr. R. Calicott (Royal Dick School of Veterinary Studies) are thanked for the provision of what was mainly slave labour. The author also wishes to take this opportunity of formally recording his gratitude to the members of staff of The Edinburgh School of Agriculture, and particularly those employed in the Advisory Nutrition and Central Analytical Services Departments, for their forbearance during his career at the School.

Acknowledgment is made of the receipt of a Studentship from the Department of Agriculture and Fisheries for Scotland.

# THESIS SUMMARY

## Thesis Summary

The investigations reported were carried out to give information upon the intake of hays of various quality (expressed as estimated metabolizable energy content, or *in vitro* organic matter digestibility) and to provide the agricultural development workers with recommendations upon the quantity of concentrate required by ewes for satisfactory performance of ewes and lambs when ewes are offered hay to appetite in late pregnancy. In addition, the intake data provided the basis for the calculation of nutrient intake of ewes, and to estimate the nutrient requirements and that quantity of nutrient necessary for satisfactory ewe and lamb performance.

The effect of hay quality upon ewe and lamb performance during the late pregnancy feeding period of the ewe was examined in a series of individual feeding trials in the months of January to March 1972, 1973 and 1974, and in group feeding investigations in 1972 and 1973. Dry matter and energy digestibility investigations were carried out concurrently using pregnant ewes and wether sheep offered similar diets. In all a total of eight hays were examined by monitoring approximately 500 pregnancies in Scottish Halfbred (Border Leicester x Cheviot) ewes.

Prior to reporting on the effect of forage quality upon voluntary intake of hay dry matter by individually fed ewes in late pregnancy, short reviews of the relevant literature on the factors affecting forage intake by both non-pregnant and pregnant ruminants are presented. Forage intake in each year of experiment was observed to be greater for the hays of better quality (as measured by estimated metabolizable energy content or *in vitro* organic matter digestibility). Relationships between forage quality and voluntary intake of dry matter for three periods during the final eight weeks of pregnancy were formulated using

the data obtained from the three years of experiment. With poor quality forages intake increased during the final eight weeks of pregnancy, but with hays of average (8.3 MJ metabolizable energy per kg DM) to above average quality intake declined. None of the forages provided sufficient nutrient to meet calculated requirement during the final week of pregnancy. Expressions relating forage quality to energy and protein intake were derived.

In order that nutrient intake be increased to above that attained by offering forages alone, concentrates are usually offered to ewes in late pregnancy. The literature on the intake of forage/concentrate mixtures by ruminants is briefly reviewed before reporting upon the effects of concentrate addition for the intake of the eight forages. The effect of the addition of a standard barley based concentrate upon forage intakes by ewes in late pregnancy was examined, with individually fed ewes receiving *ad libitum* hay plus totals of 0, 10, 20 or 30 kg (fresh weight) of concentrate during the final eight weeks of pregnancy. For example, ewes receiving totals of 30 kg of concentrate were offered 150 g per day for 17 days, 450 g per day for the next 17 days and 900 g per day for the final 22 days of pregnancy. The addition of 300 g of concentrate per day did not reduce the intakes of the eight forages examined, but larger rations of concentrate reduced forage intakes by varying amounts unrelated to the forage quality. Only those ewes offered the best quality hay tested (estimated metabolizable energy value of 10.3 MJ per kg DM; *in vitro* organic matter digestibility of 67% and crude protein of 14.8%) plus 30 kg of concentrate consumed sufficient energy and protein to meet calculated nutrient requirement during the final week of pregnancy.

To obtain estimates of the quantities of concentrate required to produce satisfactory ewe and lamb performance four of the hays were offered to appetite plus 0, 10, 20 or 30 kg of concentrate to groups of approximately 25 ewes during the final eight weeks of pregnancy. Lamb birthweights and subsequent liveweight gains to six weeks indicated that concentrate additions to the basal forage diet had little effect upon these parameters. The data indicated that the ewe may draw upon body reserves in late pregnancy without detriment to subsequent performance.

The levels of free fatty acid and ketone in the blood plasma were used to monitor the point in gestation at which the individually fed ewes on the diets supplied started to draw heavily upon body reserves. The free fatty acid levels in the plasma failed to reflect the quantity of concentrate offered. The quantities of concentrate necessary to prevent the level of plasma ketone exceeding 4 mg per cent were used to calculate the concentrate necessary to prevent detrimental effects upon body reserves. Corresponding ewe weight changes from mid-pregnancy to 24 hours *post partum* were between 6 and 10%. The point in gestation at which the blood plasma ketone levels exceeded 4 mg per cent was dependent upon hay quality. The ewes being offered the better quality hays required reduced amounts of concentrates. No concentrates were necessary for ewes offered hays of 9.8 MJ of ME per kg DM or better.

In the final discussion and conclusions the implications of the findings are set out, and it is stressed that the theoretical nutrient requirement necessary to prevent the drawing upon body reserves is in excess of that required for satisfactory performance. Recommendations are made for the concentrate necessary for the pregnant ewe offered hays of different quality to appetite during the final eight weeks of pregnancy.

# INTRODUCTION

## Introduction

Writing in 1948, after reporting on his classic experiments, Wallace discussed late pregnancy ewe nutrition. He observed that ewes which received a limited ration of hay and a liberal ration of concentrates produced lambs of similar birthweight to ewes receiving good quality hay to appetite plus a limited quantity of concentrate. He stated: "The above finding is of considerable practical importance, particularly when, as at present, concentrate feed stuffs are in short supply". Guyer and Dyer (1954) working on late pregnancy ewe nutrition also noted a forage quality effect upon lamb and ewe performance, and Reid (1958) observed that the minimum amount of any feed stuff required by the ewe at the several stages of pregnancy to ensure maximum survival and rate of growth was unknown. This observation by Reid (1958) echoes the conclusion of Wallace (1948a) that further work is required "to determine the relative value of hay and concentrate when fed in less liberal rations" to pregnant ewes.

Nutrient requirement of the ewe during early to mid-pregnancy is the same as that of the non-pregnant ewe (Agricultural Research Council 1965; National Research Council 1957, 1964, 1968; Coop and Clark 1969) when forage intake is not adversely affected by pregnancy (Forbes 1970a). Despite the estimates of nutrient requirement of the ewe in late pregnancy available (Lodge 1972), a search of the literature fails to reveal a large scale, systematic and practical approach to providing data on the relative value of hay and concentrates to the breeding ewe in late pregnancy. Advisory material (North of Scotland Agricultural College 1958, 1972; Ministry of Agriculture Fisheries and Food 1964; Cunningham 1966; West of Scotland Agricultural College 1969) recommends the feeding of various amounts of concentrate for ewes in late pregnancy, but fails to take into account the quality of the basal forage. The Meat and Livestock Commission Survey (Kilkenny personal communciation) found that farmers fed (in 1974) an average of 44 kg of concentrate to a ewe during late pregnancy. Survey results of commercial flocks in 1971 (Kilkenny 1972) and 1973 (Kilkenny 1974) showed that flocks having the best economic results used less concentrate, and this accounted for the greatest reduction of costs. A knowledge of the relative quantities of hay of different quality and the amount of concentrate necessary for satisfactory performance would provide a basis for more accurate rationing of concentrate and thus save expense in the *pre partum* feeding period.

In this dissertation the late pregnancy period is considered in the three contexts of

(i) the intake of forage alone
(ii) the intake of forage/concentrate mixtures, and
(iii) the level of nutrition required by and supplied to the ewe during the last eight weeks of gestation.

At the beginning of each section, prior to reporting on experimental work, a brief review of the relevant literature is presented. The experimental report in Section I describes a series of trials carried out in Janurary to March 1972, 1973 and 1974 to determine the quantity of hay of different quality eaten by Scottish Halfbred (Border Leicester x Cheviot) ewes during the latter eight weeks of pregnancy. Equations relating intake of forage with hay quality (estimated metabolizable energy, *in vitro* organic matter digestibility, and energy digestibility) at three stages during the final eight weeks of pregnancy are presented.

Section II is devoted to an examination of the effect of the addition of a standard cereal based concentrate to the hay diets examined in Section I. In the penultimate part of the dissertation (Section III) the energy and protein intakes achieved by ewes on experiments reported in Sections I and II are presented, and the effects of nutrient intake upon ewe and lamb performance discussed. The effect of hay quality upon energy and protein intakes are presented in regression equations. At the end of each section the results are discussed in relation to the relevant published data. The practical implications of the findings are discussed in Section IV, and pregnancy feeding recommendations are made for ewes fed to appetite on hays of different quality.

An appendix reports on a nation-wide survey of hay quality.

# SECTION I

## VOLUNTARY INTAKE OF FEED BY RUMINANTS

## Voluntary intake of feed by ruminants

1. Non-pregnant ruminants

Review of literature

(i) Introduction

Voluntary food intake and its regulation have been the subjects of considerable speculation and research, and have regularly been the subjects of comprehensive reviews (Blaxter 1950-51, 1958, 1962; Mayer 1955; Abrams 1961; Balch and Campling 1962, 1969; Campling 1966a, 1970; Conrand 1966; Baumgardt 1969, 1970; Bines 1971; Jones 1972). From this published work the consensus view appears to be that there are divers possible mechanisms controlling voluntary food intake, with different workers postulating either single, or associations of factors as the most important regulator. The recent reviews of both Balch and Campling (1969) and Jones (1972) consider the control of voluntary food intake of ruminants to be limited by two main effects:

1) physical
2) non-physical.

Physical regulation of voluntary food intake of ruminants, when diets are of low digestibility, is an established fact. The reviews of Balch and Campling (1969) and Jones (1972) consider the evidence for intake control by various blood constituents, rumen acids concentrations, nitrogen status and heat increment of digestion. Jones (1972) concludes that voluntary intake of highly digestible diets is controlled by the hypothalamus, the signals being complex and probably a combination of changes in blood and rumen metabolites concentrations and patterns. Balch and Campling (1969) consider that the main control mechanisms of voluntary intake are thermostatic, chemostatic or glucostatic, and lipostatic as well as physical. They conclude that all are of different importance at different times, dependent upon the degree of fill and the type of diet.

It is beyond the scope of the present review to deal in a comprehensive manner with the vast body of literature on the subject of voluntary intake and its metabolic regulation (full reviews on metabolic control of food intake in ruminants have been written by Baumgardt {1970} and Baile and Mayer {1970}), for the forages examined in the experiments presented were below the digestibility above which physiological regulation would play a major role. The subject of metabolic mechanisms for the regulation of voluntary food intake of ruminants is, therefore, set aside and the literature on the subjects of the effect of forage physical state and quality examined. In addition, animal size, age, species, fatness and exposure effects upon intake are considered. These factors are considered by the author important to the topic to be examined.

(ii) Intake of long forages

The work of Campling and Balch (1961), Campling, Freer and Balch (1961) and Freer and Campling (1963) showed that the quantity of feed eaten is directly related to the amount of digesta in the rumen during a meal, and the rate of disappearance of digesta from the alimentary tract (Campling *et al* 1961, 1962). Total fill governs roughage intake (Wright 1929; Blaxter, Wainman and Wilson 1961; Freer and Campling 1963; Wyatt and Blaxter 1966), but Freer and Campling (1963) demonstrated that the rate of disappearance of food from the rumen and the quantity of digesta in the digestive tract did not limit concentrate intake. Thus, there is the implication of different mechanisms of intake control for forages and concentrates.

Forbes and Carrigus (1950), Spahr, Kesler, Bratzler and Washko (1961) and Minson and Milford (1966) noted a reduction in voluntary roughage intake as the maturity of herbage advanced and the digestibility decreased. As fibre content of the forage increases the lower is the voluntary intake of forage (Wilson, Spillane and Clancy 1966; Thornton and Minson 1972). Elliot and Topps (1963) found a correlation between voluntary intake and the *in vitro* digestibility of forages, as did Donefer, Crampton and Lloyd (1960) when studying *in vitro* organic matter digestibility. Blaxter *et al* (1961), working with hays, found that voluntary intake was related to the apparent digestibility of forage energy, increasing rapidly as energy digestibility increased from 38% to 70%, and thereafter more slowly. The data of Wilson *et al* (1966) and Murdoch (1967) broadly concur with those of Blaxter *et al* (1961). Both Crampton (1957) and Raymond (1969) stress the significance of voluntary intake as a quality factor in forages.

Using published data upon dairy cow voluntary food intake, Conrad, Pratt and Hibbs (1964) determined that dry matter consumption increased with increasing concentration of the diet, but above 67% dry matter digestibility physiological factors limited intake, and, according to Forbes (1970a) and Jones (1972), is possibly influenced by nutrient requirement. Above 70% dry matter digestibility there was no association between voluntary intake of fresh herbage and digestibility in cattle (Hutton 1962a, 1962b) or sheep (Donefer *et al* 1960; Harris and Raymond 1963).

(iii) Intake of pelleted feed

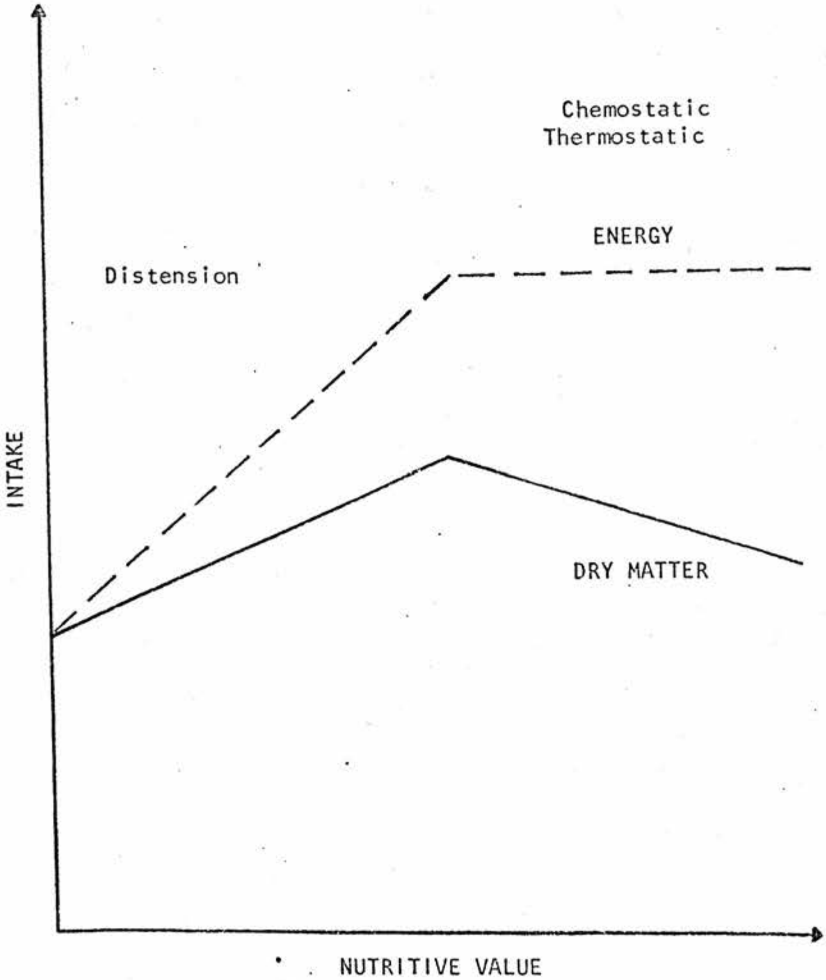
Blaxter, Graham and Wainman (1955, 1956) offered a dried grass as long material and cubed, medium and finely ground. Passage of food through the digestive tract was most rapid for the finely ground cubed material, and at higher levels of feed intake the digestibility of ground, pelleted material was less than that of long forage (Blaxter *et al* 1955, 1956). Buchman and Hemken (1964), Fontenot and Hopkins (1965), Rochette, Belzile and Holtmann (1971), Greenhalgh and Wainman (1972) and Greenhalgh and Reid (1973) broadly concur with such findings, and demonstrated an increase in voluntary food intake brought about by grinding and pelleting. However, Campling *et al* (1963), Minson (1963), Moor (1964), Campling and Freer (1966), Campling (1966a) and Campling and Milne (1972) state that grinding and pelleting does not always increase intake, especially in dairy cows (Campling and Milne 1972).

Milled and pelleted roughage is retained in the rumen for a shorter time than long forage (Blaxter *et al* 1955, 1956; Campling 1966a; Greenhalgh and Wainman 1972), with the consequence that the rumen can achieve a greater throughput, so intake is higher (Greenhalgh and Wainman 1972). Some components of the feed are less well digested in the rumen (Thomson, Beever, Coelho da Silva and Armstrong 1969, 1972; Greenhalgh and Wainman 1972) and there is an increase in efficiency of digestion in the lower gut (Thomson *et al* 1972).

The nutritive value per unit of dry matter of processed roughage will depend primarily upon the stage of maturity of the forage at harvest (Buchman and Hemken 1964; Campling and Milne 1972), and it has been found that the lower the nutritive value of the roughage the greater is the effect of grinding and pelleting on intake (Campling 1966a; Greenhalgh and Wainman 1972; Campling and Milne 1972). The particle size in the cube will govern the extent of change in intake (Rodrigue and Allen 1960; Greenhalgh and Wainman 1972) and digestibility (Blaxter *et al* 1955, 1956; Rodrigue and Allen 1960; Greenhalgh and Wainman 1972).

Figure 1.1

General relationship between food nutritive value and voluntary intake of food by ruminants




Montgomery and Baumgardt (1965a)

The finer the particle size the higher is the intake (Milne and Campling 1972).

Intake and digestibility differences brought about by grinding and pelleting alter the relationship between voluntary food intake and forage digestibility. The data of Donefer, Lloyd and Crampton (1963), Montgomery and Baumgardt (1965b) and Dinius and Baumgardt (1970) indicate that intake of a pelleted diet is also regulated by the ruminant's capacity with materials of low digestibility, but physiological mechanisms limit voluntary intake when digestibility of the dry matter is above 66%. This relationship may explain the conclusions of Conrad *et al* (1964) that 67% dry matter digestibility was the point above which the relationship between intake and digestibility became less definite with dairy cows, for the concentrate fraction of some diets was pelleted. Montgomery and Baumgardt (1965a) suggest that the definite relationship between intake and feed digestibility may be non-existent above a digestibility level of as low as 56% dry matter digestibility (in dairy heifers).

Montgomery and Baumgardt (1965a) have propounded a theory relating feed intake regulation to the energy concentration of the feed eaten (see Figure 1.1). They suggest that with feeds of low digestiblity there is a physical regulation of intake which is dependent upon food digestibility, but with feeds of higher digestibility some chemical or thermal mechanism limits voluntary intake. The observations of Donefer *et al* (1963), Montgomery and Baumgardt (1965b) and Dinius and Baumgardt (1970) obtained with pelleted feeds support the theory, and the data of Donefer *et al* (1960), Blaxter *et al* (1961), Hutton (1962a, 1962b) and Murdoch (1967) suggest that the relationship holds for long forages, but the point at which physiological control of intake takes over will be different.

(iv) Palatability

In reviews of the literature on voluntary food intake by ruminants, Baumgardt (1969), and Goatcher and Church (1970) suggested that taste and smell play an important role in controlling voluntary intake, and Goatcher and Church (1970) concluded that those senses are involved in both long- and short-term intake regulation. The investigations of Greenhalgh and Reid (1967, 1971), Huber and Cook (1969) and Van Nickerk, Greenhalgh and Reid (1973) lend support to their conclusions.

(v) Body size, age and species

Intake has been found to be related to body weight (Ferguson 1956), and Blaxter *et al* (1961) suggested that intake varied approximately with metabolic body size ($weight^{0.734}$). Cipollini, Burch, Schneider, Lucas and Paulech (1951), reviewing intake and digestibility trials in both sheep and cattle, concluded that there was a between species difference, as did more recently Buchman and Hemken (1964) and Vander Noot, Cordts and Hunt (1965). Murdoch (1967) and Greenhalgh and Reid (1972), contrary to the observations of Blaxter and Wilson (1963), found that the intake of hays by bovines was higher than that of sheep per unit of $bodyweight^{0.734}$. Working with adult sheep and lambs, Hadjipieris, Jones and Holmes (1965) and Crabtree (1967) found that older sheep ate more than lambs, but when appetite was expressed in units of intake per unit of $bodyweight^{0.734}$, the younger sheep ate more than the adults. Size, species and age may affect voluntary intake of food, and Crabtree and Williams (1971b) suggest there may even be a between breed difference in intake. {More comprehensive reviews of the affect of size, species and age upon voluntary food intake have been compiled by Vander Noot, Cordts and Hunt (1965) and Balch and Campling (1969)}.

(vi) Fatness

Tayler (1959), measuring grass consumption in cattle, noted that voluntary intake declined as animals became fatter, and explained that the phenomenon was the result of fat deposits in the abdominal cavity pressing on the rumen, thus reducing capacity. Schinckel (1960), Graham (1969), Foot (personal communication) and Orr (personal communication) found a progressive decline in voluntary intake as sheep became fatter, and Osborne (1971) noted that the intake of fat sheep was less than that of thinner animals. Bines, Suzuki and Balch (1969) showed that cows when thin ate 30% more hay, and 23% more hay and concentrates than when fat, and Foot (1972) found that thin ewes ate 106 g/kg$W^{0.73}$, while fat ewes consumed 68 g/kg$W^{0.73}$. Kennedy (1961) proposed a lipostatic control of intake, but Bines *et al* (1969) and Foot (1972) do not attribute their findings to such a mechanism.

(vii) Exposure

Minson and Ternouth (1971), Weston (1971) and several workers (see Ternouth and Beattie 1970) have noted that voluntary intake of feed by sheep increases by 15% or more after shearing, possibly due to the doubling of heat production of sheep when closely clipped described by Blaxter *et al* (1959). Weston (1970) noted that voluntary intake increased by 9% when sheep were exposed to cold.

(viii) Summary and conclusions

Prior to considering the effect of pregnancy upon food intake it is necessary to accept that the intake of a forage by ruminants is subject to the constraints of hay quality, whether measured by fibre content or digestibility of dry matter, energy or organic matter (or some index incorporating these measurements). Voluntary intake of long forages is controlled by forage dry matter and/or energy digestibility up to 70%. When forage is ground and pelleted voluntary intake is determined by its dry matter digestibility up to 66%. Once digestibility is above 70% (long forages) or 66% (pelleted feed) some form of metabolic control intervenes.

Bonnecarrère (1973) in a recent review on the causes of variability in intake between forages concluded that a combination of some measure of fibrousness with a measure of digestibility or rate of digestion of this fraction may provide a useful index of forage quality. The above review permits similar conclusions. To evaluate the feed potential of forages it is necessary to include a component to test the forages under conditions for which they are intended. A review of the published studies reveals that there is inadequate information on the evaluation of hays as feeds for pregnant ewes.

In addition to forage quality animal size, species, age, fatness and exposure will to some extent affect voluntary intake of food by ruminants, and not necessarily in that order.

## 2. Pregnant ruminants

### Review of literature

#### (i) Introduction

Many comparisons of voluntary food intake of pregnant and non-pregnant ruminants have been made, but deal mainly with the final few weeks of pregnancy. Campling (1966b), Johnson, Trimberger, Wright, Van Vleck and Henderson (1966), Lambeth (1969) and Jordan, Lister, Wauthy and Comeau (1973) report intakes of pregnant cows to be less than those of dry cows. Similar data for the non-pregnant and pregnant ewe are provided by Gordon and Tribe (1951), Hadjipieris and Holmes (1966) and Forbes (1970a).

#### (ii) Early pregnancy

Snapp and Bull (1944) noted that pregnant beef heifers ate more rapidly than their non-pregnant counterparts, and postulated an increase in appetite with pregnancy. The data of Johnson *et al* (1966), obtained from dairy cows, although confounded by the effects of lactation, show a steady decline in intake during pregnancy. Increases in ewes' intakes of hays (Forbes 1970a, 1970b; Russel personal communciation) and grass (Owen and Ingleton 1963) during early to mid-pregnancy have been reported, possibly due to the greater nutrient requirement of pregnancy (Forbes 1970a, 1970b), but the data of Gordon and Tribe (1951) do not indicate a change in voluntary food intake during this stage of gestation.

#### (iii) Late pregnancy

There are conflicting reports on the voluntary intake of feeds by cattle during the final few weeks of pregnancy. A reduction in roughage intake during the last three or two weeks of pregnancy has been measured by Mäkelä (1956), Campling (1966b), Curran, Campling and Holmes (1967), Dijkstra (1971) and Jordan *et al* (1973). Broster, Tuck and Balch (1964) and March, Curran and Campling (1971) did not find a steady decrease in intake in late pregnancy, but Marsh *et al* (1971) state that intake was much reduced during the final four or three days immediately pre-parturition.

A reduction in the voluntary intake of ewes during the last few weeks of pregnancy, whether offered hay (Gordon and Tribe 1951; Hadjipieris and Holmes 1966; Forbes 1970a, 1970b, 1971) or silage (Cooper 1966; Forbes, Rees and Boaz 1967; Forbes 1970a; Rutter, Laird and Broadbent 1971) or dried grass (Hadjipieris and Holmes 1966) or grazing (Owen and Ingleton 1963) has been widely reported. There are some reports in which a reduction in voluntary intake of ewes in late pregnancy did not occur when offered hay (Foot and Greenhalgh 1969; see Forbes 1970a) or silage or dried grass (Sheehan and Lawlor 1972).

(iv) Control of voluntary intake during pregnancy

a) Physical control

Reid (1958), Owen and Ingleton (1963), Hadjipieris and Holmes (1966) and Sheehan and Lawlor (1972) have reported that during late pregnancy twin bearing ewes ate less than those carrying single lambs, and Hadjipieris and Holmes (1966) noted that triplet bearing ewes ate less than ewes carrying twins. Gordon and Tribe (1951), Reid (1958), Schinckel (1960) and Reid and Hinks (1962a) found even greater intake reductions in fat twin bearing ewes. Davies (1962) noted that a diminution in rumen size reduced voluntary forage intake by ewes, and the work of Forbes (1968, 1969a, 1970a) confirmed the additive effects of pregnancy and fatness in the ewe, demonstrating an inverse relationship between the volume of "incompressible" abdominal contents (uterus + abdominal fat + empty digestive tract + liver + spleen + kidneys) and the volume of rumen contents, which declined from 9.0 litres during the 14th week of pregnancy to 5.5 litres at the 20th week of gestation. Lankeit, Witt, Farries and Djamai (1966) demonstrated that cow fatness and foetal size affected forage intake by cattle in late pregnancy. These observations are in agreement with the speculations of Mäkelä (1956) on cattle and Blaxter (1957) on sheep, that fatness and the increase in uterine volume caused the often observed reduction in voluntary intake in late pregnancy.

Everitt (1966) fed ewes to cause a 15% increase or decrease in body weight during the first 13 weeks of pregnancy, and subsequently found that fat ewes (15% increase in body weight) consumed 1.5% of body weight per day, while the thin ewes (15% decrease in body weight) ate 3.4% of body weight per day, with late pregnancy intake decline starting several weeks earlier in the fat ewes. A similar investigation by Foot and Greenhalgh (1969) demonstrated that thin pregnant ewes ate 28% more hay than fat pregnant ewes, but there was no late pregnancy decline in voluntary food intake. Bereskin and Touchberry (1967) demonstrated an increase of 5% in the girth of pregnant cows: any change in intake due to fatness or increased uterus size may possibly be confounded by stretching.

b) Physiological control

It has been shown that foetal load and fatness will affect the voluntary intake of feed during the latter stages of pregnancy (see above). However, Forbes (1968, 1969a, 1970a, 1970b) has pointed out that the decline in voluntary intake of ewes in late pregnancy is proportionally less than the reduction in the rumen volume, for there is an increased rate of passage of digesta through the alimentary tract with advancing pregnancy (Graham and Williams 1962; Forbes 1969a, 1971) possibly associated with the observed increase in ruminating time (Campling 1966b; Forbes 1969a, 1970a). Foot and Greenhalgh (1970) demonstrated a limited negative correlation between body fat and alimentary tract contents with a gradual decline in forage intake, but concluded that it was unlikely that physical restriction played more than a minor role in limiting voluntary intake.

The data of Hadjipieris and Holmes (1966), Marsh *et al* (1971) and Sheehan and Lawlor (1972) provided limited evidence that the higher the quality of the fodder the greater was the intake during late pregnancy, and Rochette *et al* (1971) have shown that by offering the forage in a pelleted form in pregnancy voluntary intake is increased. Forbes (1970a, 1970b) reports a decline in voluntary intake of ewes fed to appetite on barley plus approximately 0.1 kg of roughage during the final four weeks of pregnancy. Owen, Miller and Bridge (1968) found intake of concentrates, plus varying levels of milled straw by heifers, to be less in the ninth month of gestation than in the eighth month, and Aitken and Preston (1964) report a reduction in intake of milled complete rations for dairy heifers. These reports, plus the observations of Foot and Greenhalgh (1970) indicate that despite highly digestible rations, when non-physical factors would control intake, there was a decline in voluntary intake in late pregnancy, thus suggesting that some metabolic control of intake peculiar to late pregnancy is present. Duncan (1973), however, when offering *ad libitum* concentrate diets found that intake of ewes did not decline as pregnancy advanced, irrespective of foetal burden (one to three).

Reid and Hinks (1962a) first postulated that some metabolic factor(s) may control the voluntary intake of pregnant ewes, when they found that fat pregnant ewes, being undernourished as a result of a marked decline in voluntary intake, were better able to maintain blood glucose and hence maintain blood ketones in the normal range, than ewes in medium or poor condition, but birthweights and viability of twins were low. Reid and Hinks (1962a) offer no explanation of, or mechanism for metabolic control of intake in late pregnancy. Forbes (1971) suggests that there may be hormonal control of voluntary intake, and reports that oestrogen, the rate of secretion of which increases markedly during the final few weeks of pregnancy in cattle and sheep (Robinson 1957), injected intravenously into wether sheep caused a marked decrease in the intake of concentrates, but not of hay.

(v) Summary and conclusion

Voluntary intake of ruminants during pregnancy is subject to most of the limitations of non-pregnant animals, but in addition there appears to be a decline in voluntary food intake during late pregnancy, especially in multiple bearing ewes, due to either physical limitations imposed by uterine enlargement or metabolic changes brought about by pregnancy, or a combination of the two. The extent of intake depression is likely to be governed by foetal load, degree of fatness and the type of feed offered.

Although the literature contains many reports (see above) on relationships between forage quality and voluntary intake by non-pregnant ruminants only limited information is available upon intake of forages of different quality by ewes in late pregnancy. A search of the literature does not reveal a verification of the view that forage quality governs voluntary intake of dry matter of ewes in late pregnancy when voluntary roughage intake is likely to be depressed and nutrient requirement increasing rapidly (see below).

3. Voluntary intake of forages by pregnant ewes

Experimental report

(i) Introduction

Reviewing the literature indicated that forage quality, whether expressed as forage fibre content or component digestibility, effectively governed the intake of forages by non-pregnant ruminants, and that the very limited data upon intake of roughages by ewes in late pregnancy failed to systematically evaluate roughages as sole feeds for ewes in late pregnancy. To verify the view that better quality hay is eaten in greater quantity than poor quality hay a series of intake trials were carried out on hays of different quality. The effects of ewe fatness and litter size upon intake have been pointed out and the trials reported below included a component to monitor those factors.

The trials reported in this section were carried out to determine the quantity of forage ingested when offered as sole food, and to provide a basis for calculating the potential nutrient intake of ewes during late pregnancy when offered hay alone. The nutrient intakes are reported below (see Section III). Investigations on the effect of concentrate upon hay intake (Section II) were to supply information from which total nutrient ingested could be calculated.

A range of hay qualities was required for test. In the first year of investigation hays already made on the farms of The School of Agriculture were used. In the subsequent years it was possible to have grass cut when required, the best quality hays being made from grass cut shortly after ear emergence and subsequently being won with little or no weathering. The poor quality forages were obtained from more mature stands of grass, or grass subjected to weathering before baling. All hays were made in the field, baled, stored in sheds and blown with cold air if necessary. Hays were sampled prior to feeding trials and subjected to chemical analysis to obtain an indication of feed value.

(ii) Materials and methods

Scottish Halfbred ewes (Border Leicester x Cheviot), diagnosed as pregnant (Doppler Fetometer - Centaur Edinburgh) to Suffolk rams, weighing on average approximately 75 kg in Experiments 1.1 and 1.2, and 81 kg in Experiment 1.3, were housed eight weeks prior to parturition in individual pens measuring 1.6 x 1.2 metres. Ewes remained in individual pens until approximately two days after lambing in late March and were then turned to grass with their lambs.

To minimise waste at the feed box (tomb stone type), the forages on test were chopped with a precision chop forage harvester (length 5-10 cm) and offered to appetite throughout the eight week pre-parturition period. Fresh water was on offer at all times, and wheat straw bedding supplied as necessary. Hays were sampled regularly and analysed by the Advisory Nutrition Department of The Edinburgh School of Agriculture, and the estimated metabolizable energy values of the forages calculated from the fibre and crude protein contents of the forages using equations derived by Alderman, Collins, Jones, Morgan and Ibbotson (1966). The fodders were weighed into two kilogram lots, the quantity offered recorded, and the refusals bulked and weighed twice weekly. Ewes were fed before 08:00 hours, and feed boxes were replenished at noon and at 17:00 hours.

Ewes were weighed regularly at two week intervals from before mating to weaning, with body scoring (Russel, Doney and Gunn 1969) and further weighings at mating, housing and 24 hours after lambing. Lambs were weighed, tagged, navel dipped with iodine, and castrated and tailed (rubber ring method) during the first few hours of life. Ewes were checked for availability of milk at lambing.

Energy and dry matter digestibility of the hays were determined with pregnant ewes, or wethers in metabolism cages similar to those described by McDonald, Edwards and Greenhalgh (1973). Each estimate of hay energy and dry matter digestibility was calculated from the mean of either three or four determinations of digestibility. In addition *in vitro* determinations of hay organic matter digestibility were made using the method of Alexander and McGowan (1966).

The data were analysed using statistical techniques suggested by Snedecor (1956). The Appendix contains a table to illustrate the form of printout of analysis obtained from the computer.

The manufactured constant of Complete Ruminant Diet (AA7 - Animal Breeding Research Organisation) to act as a basis for comparison of data obtained in different years was unavailable for the first set of trials, but was obtained for the subsequent investigations.

The forage intake studies plus concurrent individual feeding and digestibility trials with mixtures of hay and concentrate (see Section II) proved to be exceptionally laborious with the weighing equipment available (Avery - Semi-self-indicating scale type 1301 BCD). The chopping of up to 1.5 tonnes of each hay at one time using a precision chop forage harvester permitted the preparation of approximately five tonnes of hay in two to three hours. Ideally hay refusals should have been weighed each day, but this exercise was not possible on the available equipment. It was, therefore, impossible to follow the strict regime of offering a fixed quantity in excess of the previous daily intake, as suggested by Blaxter *et al* (1961). The adoption of a technique in which two kilogram bags of hay were offered in several feeds much reduced the work load. The forages were offered in a manner which ensured that refusals in the feed box prior to the first morning feed were kept to approximately 250 g fresh weight.

Table 1.1

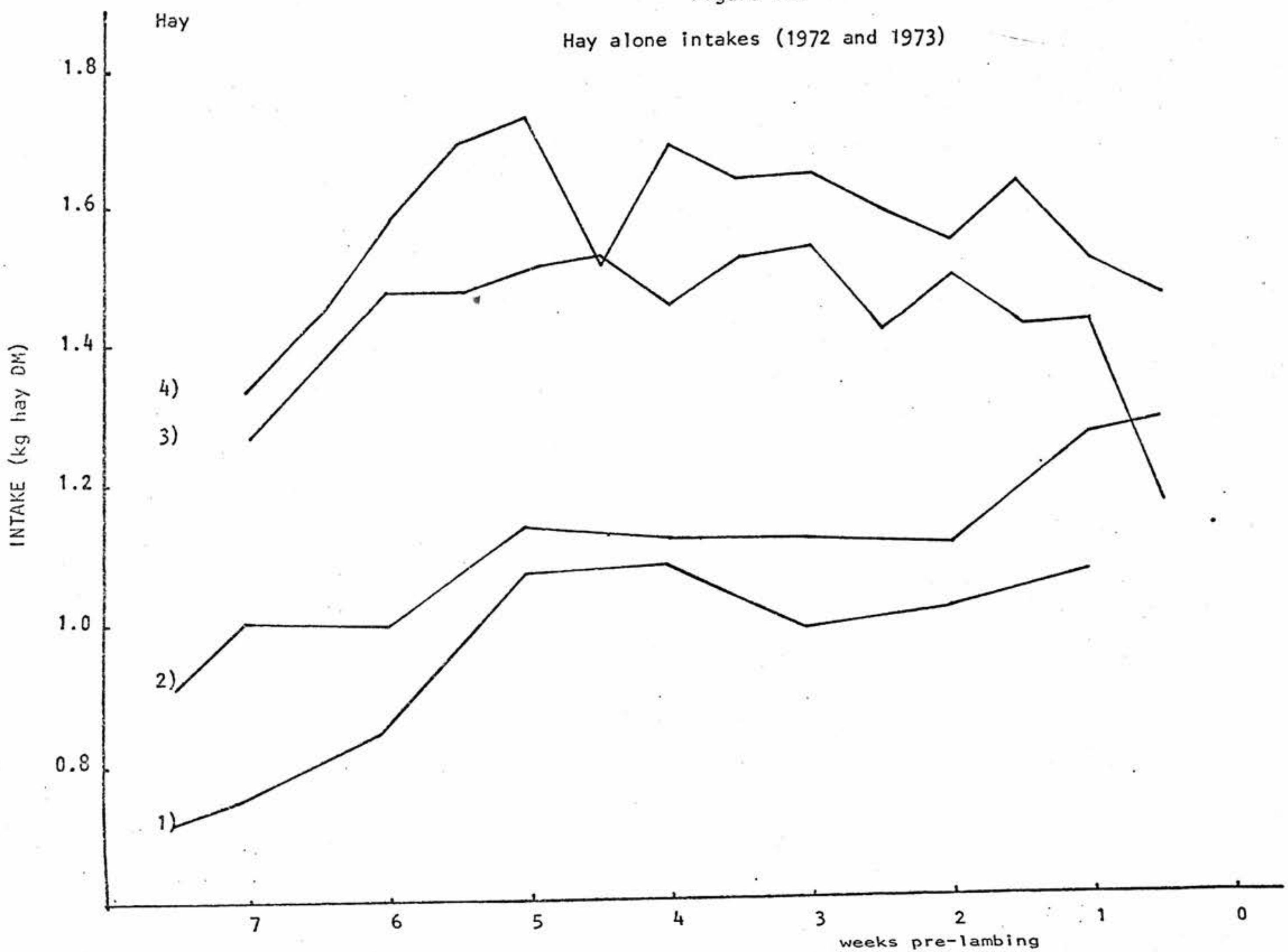
Protein, energy, dry matter and organic matter digestibility of hays examined

| Year | Hay | Crude protein % | Estimated metabolizable energy (MJ/kg DM) | I.V.O.M.D.* % | *In vivo* digestibility | |
|---|---|---|---|---|---|---|
| | | | | | energy | dry matter |
| 1972 | 1 | 7.7 | 6.27 | 44 | - | - |
| | 2 | 8.5 | 7.74 | 51 | 51 | 52 |
| 1973 | 3 | 8.6 | 8.80 | 57 | 60 | 62 |
| | 4 | 14.8 | 10.30 | 67 | 64 | 67 |
| | CRD | 14.2 | 11.30 | - | - | - |
| 1974 | 5 | 7.6 | 6.70 | 47 | 50 | 50 |
| | 6 | 7.9 | 7.60 | 48 | 57 | 58 |
| | 7 | 7.4 | 7.90 | 51 | 56 | 58 |
| | 8 | 8.2 | 8.40 | 53 | 61 | 62 |
| | CRD | 14.2 | 11.30 | - | - | - |

*I.V.O.M.D. = *in vitro* organic matter digestibility

Figure 1.2

Hay alone intakes (1972 and 1973)



(iii) Results

Experiment 1.1

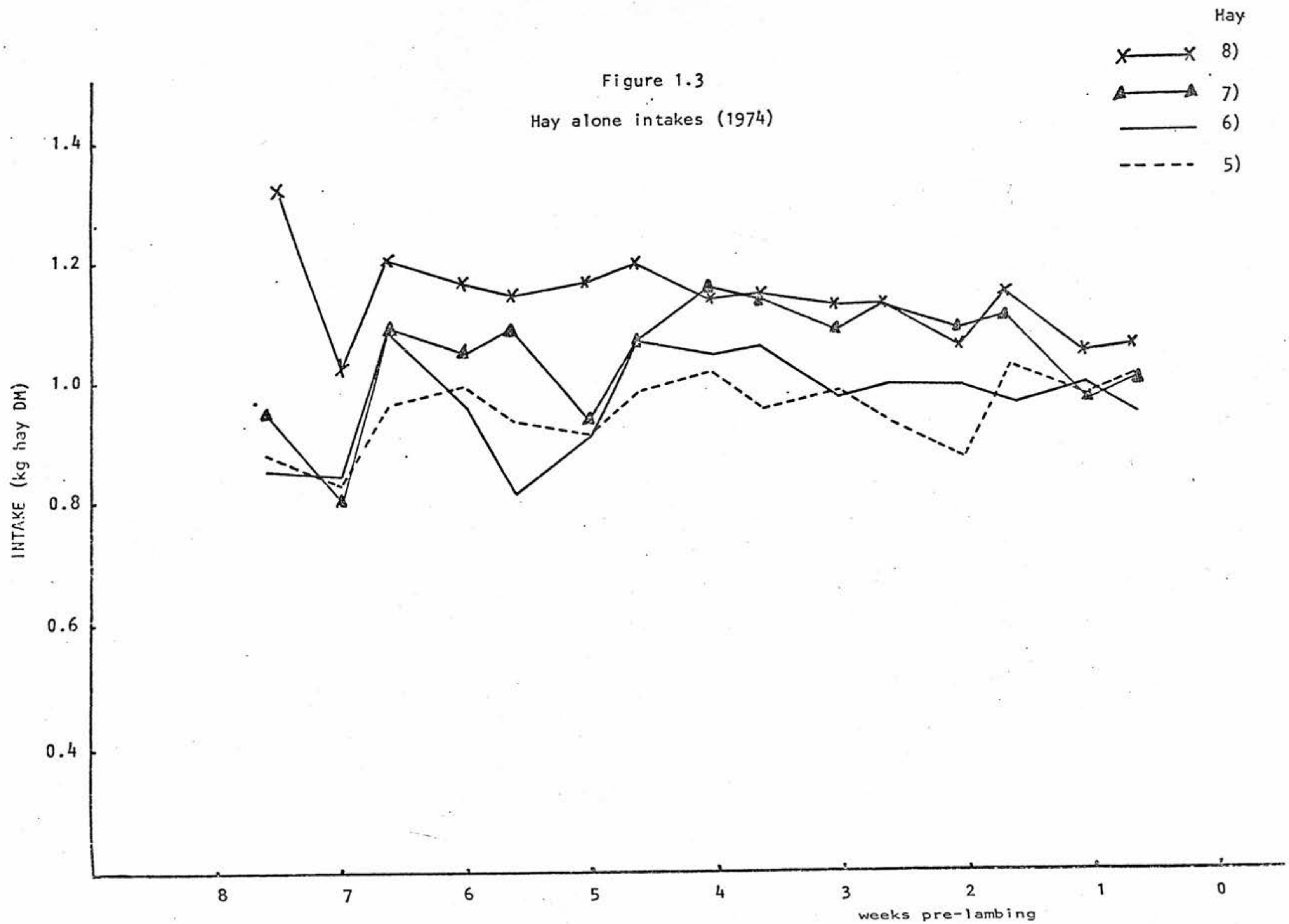
In January to March 1972 hays 1) and 2) of estimated metabolizable energy values of 6.27 and 7.74 MJ per kilogram dry matter and 7.7 and 8.5 per cent crude protein respectively (see Table 1.1) were each offered *ad libitum* to four ewes during the final eight weeks of pregnancy. Intake patterns of both hays were similar (see Figure 1.2), the initial sharp rise in intake becoming more gradual, with no depression of intake during the final three weeks of pregnancy. Voluntary intake was much reduced on the day before parturition. Throughout the period of test voluntary intake of hay 2) was in excess of hay 1) [see Figure 1.2 and Table 1.2]. Pregnant ewes on concurrent digestibility trials, and *in vitro* digestibility studies gave the energy, dry matter and organic matter digestibility values shown in Table 1.1 Intake is expressed as g dry matter per kg bodyweight$^{0.75}$ for three periods during the final eight weeks of pregnancy (see Table 1.2).

Experiment 1.2

Similar investigations to experiment 1.1 were carried out in January to March 1973 on hays 3) and 4) of estimated metabolizable energy values of 8.8 and 10.3 MJ per kilogram dry matter and 8.6 and 14.8 per cent crude protein respectively (see Table 1.1). Each hay was offered to six ewes. Intake patterns of both hays were similar with an initial sharp rise in intake (see Figure 1.2). Hay consumption declined with advancing gestation, the intakes of hays 3) and 4) declining from three weeks and from five weeks prior to parturition respectively.
The intake of hay 4) was greater than that of hay 3) throughout the period of test (see Figure 1.2 and Table 1.2). Six individually penned ewes of similar physiological state and weight were offered complete ruminant

Figure 1.3

Hay alone intakes (1974)



diet (AA7 - Animal Breeding Research Organisation) to appetite throughout the period of test. The initial sharp rise in intake of complete ruminant diet declined steadily from five weeks prior to parturition, and dry matter intake was much in excess of those ewes offered hays 3) and 4) during the periods under consideration (see Table 1.2). Voluntary intake of all feeds was much reduced during the 48 hours prior to lambing. Concurrent digestibility studies with pregnant ewes and wethers and *in vitro* digestibility studies gave the energy, dry matter and organic matter digestibility values shown in Table 1.1. In Table 1.2 intake is expressed as g dry matter per kg bodyweight$^{0.75}$ for three periods during the final eight weeks of pregnancy.

Experiment 1.3

Further studies on hay intakes by pregnant ewes were carried out in January to March 1974 on hays 5), 6), 7) and 8) of estimated metabolizable energy values of 6.7, 7.6, 7.9 and 8.4 MJ per kilogram dry matter, and 7.6, 7.9, 7.4 and 8.2 per cent crude protein respectively (see Table 1.1). Four ewes were offered each hay. Intake patterns throughout the eight week feeding period were variable (see Figure 1.3). With all hays on test initial intakes dropped, then recovered, and thereafter intakes of hay 5) gradually increased until parturition. Intake of hay 6) was constant from three weeks pre-lambing (see Figure 1.3) while with hays 7) and 8) intake declined, with minor deviations, from the fourth week prior to parturition. The mean daily intake of each forage over the whole feeding period in ascending order was 5), 6), 7) and 8), the intakes of hays 5) and 6) being almost equal.
A similar group of four individually penned ewes were offered complete ruminant diet to appetite throughout the feeding period. As in Experiment 1.2, consumption of complete ruminant diet initially increased

Table 1.2

Voluntary intake of hay (g/kg $W^{0.75}$ ±SE)
by pregnant ewes at three stages during the final weeks of gestation

| Period | | I | II | III |
|---|---|---|---|---|
| Year | Hay | 6 weeks pre-lambing | 4 weeks pre-lambing | 1 week pre-lambing |
| 1972 | 1 | 29.5 ±4.08 | 42.2 ± 5.93 | 41.6 ± 5.39 |
| | 2 | 42.8 ±3.12 | 44.0 ± 2.58 | 49.9 ±3.31 |
| 1973 | 3 | 56.2 ±3.28 | 58.1 ± 2.23 | 55.3 ±2.00 |
| | 4 | 65.1 ±2.84 | 65.7 ± 2.90 | 62.8 ±4.73 |
| | CRD | 95.6 ±5.00 | 86.7 ± 7.69 | 89.7 ±5.81 |
| 1974 | 5 | 35.8 ±3.33 | 36.8 ± 4.82 | 37.9 ±7.74 |
| | 6 | 33.3 ±0.81 | 39.1 ± 5.49 | 37.3 ±3.88 |
| | 7 | 38.2 ±2.90 | 39.8 ± 4.69 | 37.5 ±2.26 |
| | 8 | 41.6 ±1.62 | 41.5 ± 2.02 | 39.4 ±3.14 |
| | CRD | 97.1 ±4.63 | 87.1 ±12.29 | 79.1 ±3.74 |

W = bodyweight of ewe at housing

and then declined from five weeks prior to parturition. During the 48 hours prior to lambing intake of all feeds was much reduced.

Observed energy and dry matter digestibility of hays (see Table 1.1) proved higher than anticipated from the laboratory chemical analysis, but dry matter intake of ewes was below that observed with hays of similar or even lower digestibility (see Table 1.2). The observed digestibility of energy and dry matter did not follow the same pattern of quality as estimated by the metabolizable energy value of the hays (see Table 1.1). Hay consumption by the ewes broadly followed the estimated metabolizable energy and organic matter digestibility of the hay. In concurrent studies food consumption by the wethers used to determine hay energy and dry matter digestibility followed the relationship between hay energy and dry matter digestibility, and voluntary intake. Dry matter intakes by wethers were 19.3, 22.9, 22.3 and 23.2 g per kilogram bodyweight (51.8, 65.0, 62.7 and 66.2 g per $kgW^{0.75}$) for hays 5), 6), 7) and 8) respectively. Table 1.1 shows the digestibility of dry matter, energy and organic matter of the hays. No explanation for the discrepancy in the data is apparent. Ewe intakes of feeds are expressed as g dry matter per kg $bodyweight^{0.75}$ for three periods during the final eight weeks of pregnancy (see Table 1.2).

(iv) Discussion and conclusions

Although it is arguable as to the validity of comparisons on data obtained in different years, the intake data of the control diet (complete ruminant diet) was similar for each year of offer (see Table 1.2). In each year of experimentation animals were of similar breed, size, and had mean litter sizes of approximately 200%. Housing, labour, management and handling facilities remained constant. Intake graphs of hays 1), 2), 3) and 4) are included on the same diagram to illustrate

Figure 1.4

Relationship between hay estimated metabolizable energy concentration and dry matter intake

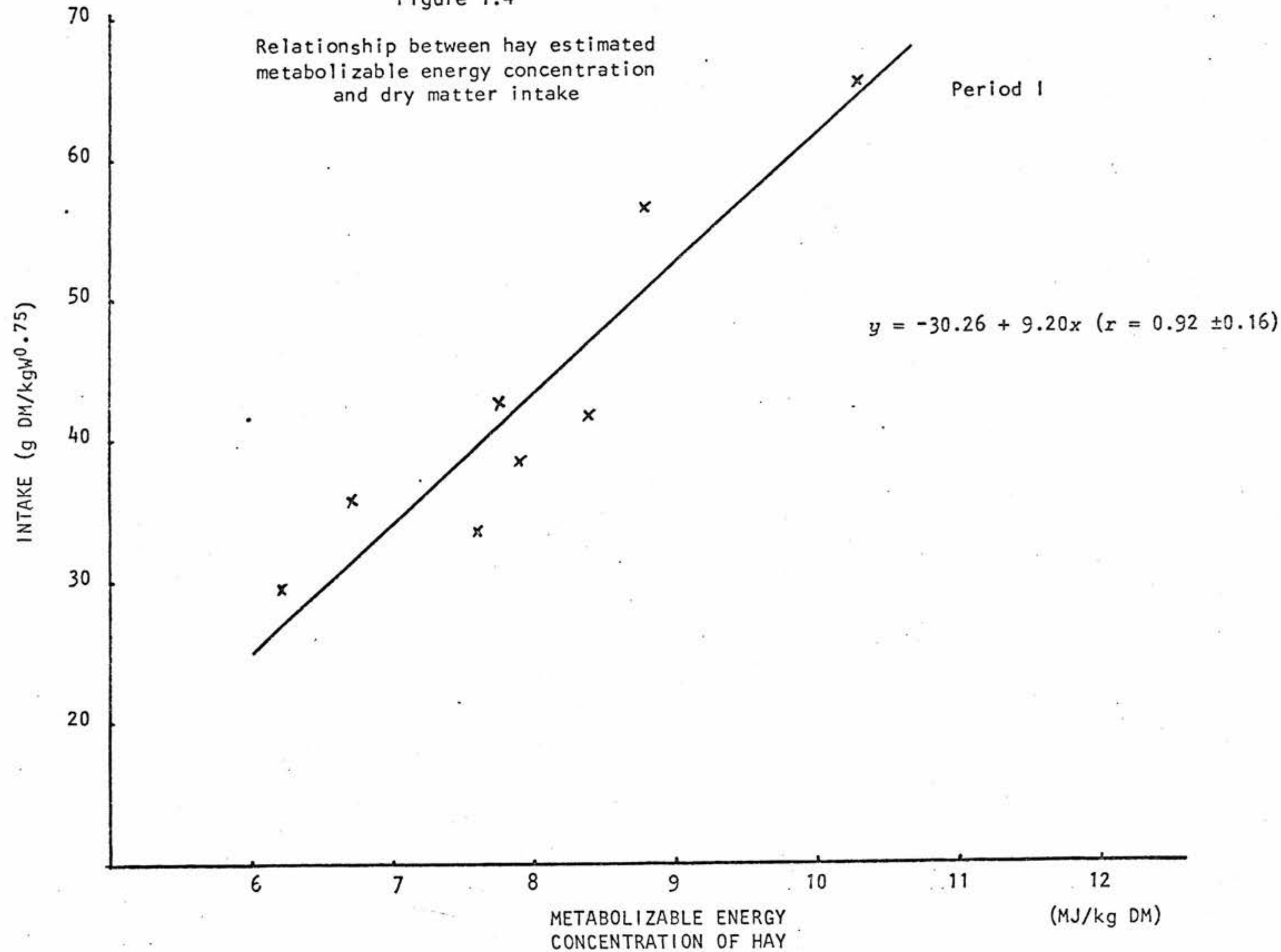


**Figure 1.5**

Relationship between hay estimated metabolizable energy concentration and dry matter intake

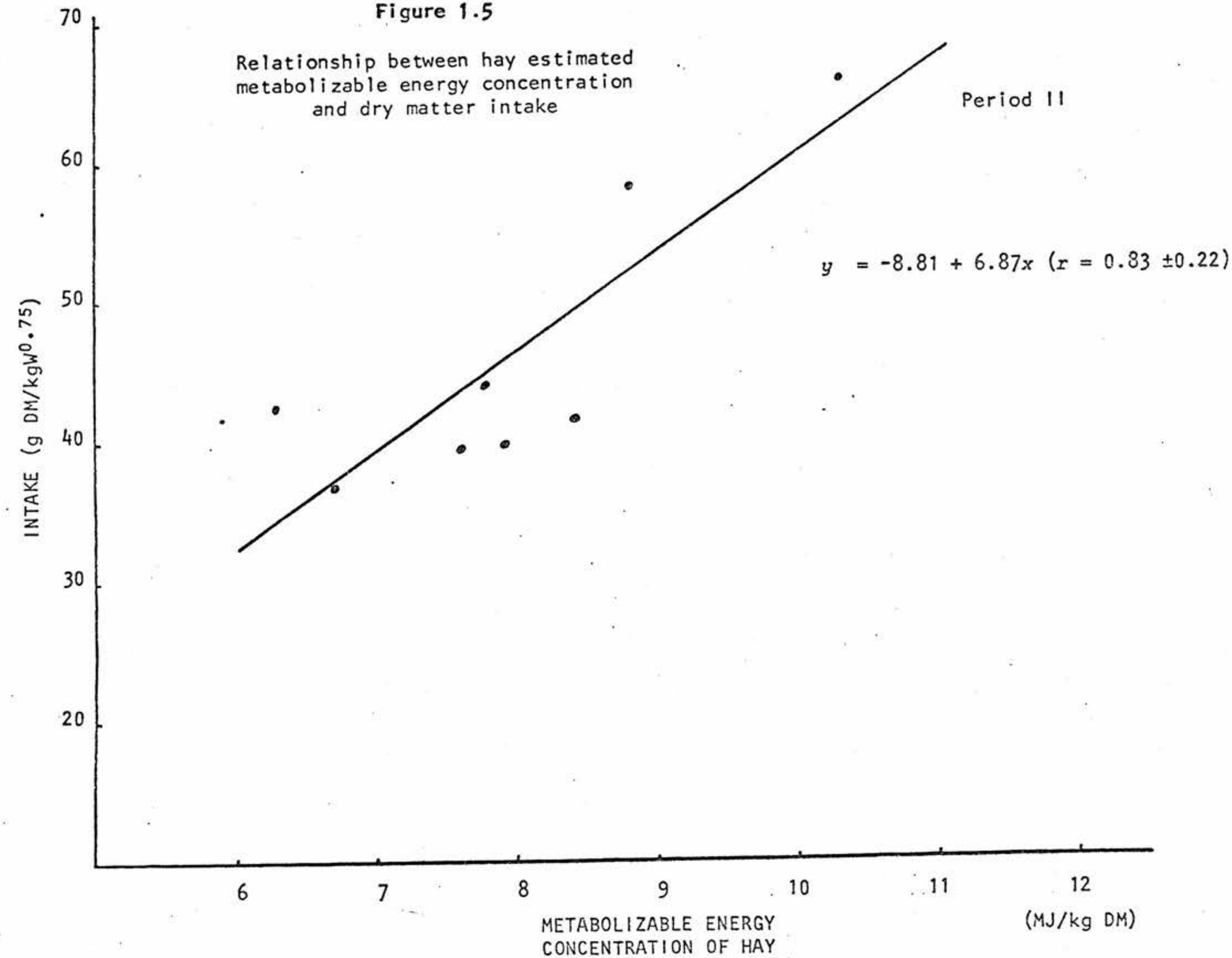
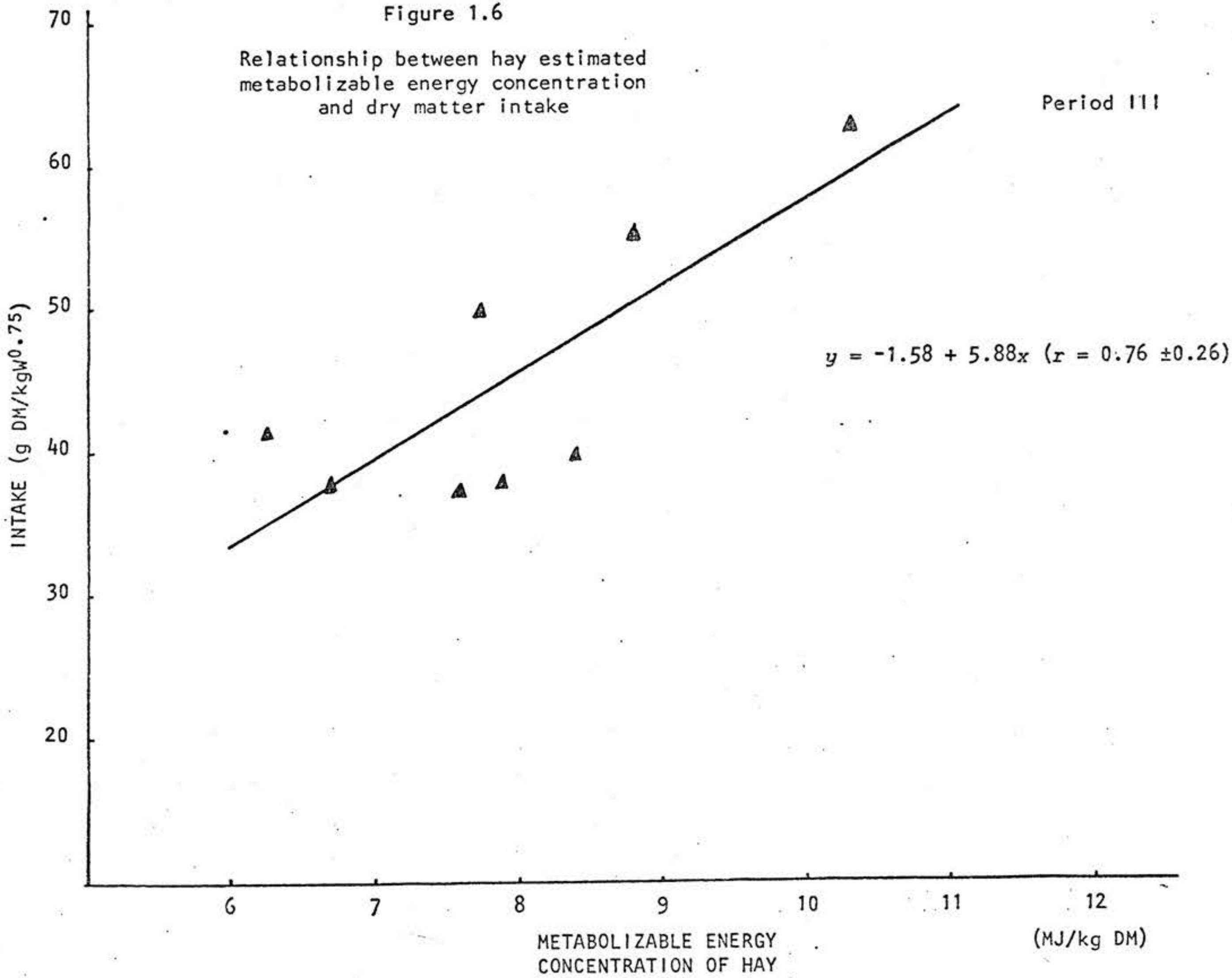


Figure 1.6

Relationship between hay estimated metabolizable energy concentration and dry matter intake



the large differences of intake between hays of extreme quality. By presenting the data in terms of metabolic bodyweight (grams per kilogram bodyweight$^{0.75}$) any effects on intake brought about by differences in ewe weights are eliminated. Data are presented on intake measured at three points during the period of test (see Table 1.2). It is evident that in each year the better the quality of the hay (as measured by estimated metabolizable energy value and *in vitro* organic matter digestibility), the greater was the intake, thus agreeing with data obtained from both non-pregnant (Blaxter *et al* 1961; Blaxter and Wilson 1963; Murdoch 1967) and the very limited data from pregnant sheep (Hadjipieris and Holmes 1966; Sheehan and Lawlor 1972).

Voluntary hay intakes in Experiment 1.3 were below the level that would be predicted on the basis of chemical analysis and reference to the intakes measured in Experiments 1.1 and 1.2. However, mean body condition scores (±SE) of ewes were 2.8 (±0.2) and 3.3 (±0.4) at the start of the experimental period for Experiments 1.1 and 1.3 respectively. Fatness has been shown to affect intake of pregnant ewes (Everett 1966; Foot and Greenhalgh 1970; see below) and may to some extent explain the discrepancy.

Pooling intake and energy digestibility data for the three sets of investigations showed that in period I intake was correlated with observed energy digestibility ($r = 0.75 \pm 0.27$), but in periods II and III the correlations were much reduced ($r = 0.60 \pm 0.33$, and $r = 0.46 \pm 0.36$). The relationship between intake and estimated metabolizable energy concentration of the feed was much stronger and Figures 1.4, 1.5 and 1.6 illustrate the situation. The pooled data for hay intake and estimated metabolizable energy values were subjected to regression analysis for the three periods, and the following expressions relating intake and estimated metabolizable energy concentration derived:

Figure 1.7

Relationship between hay *in vitro* organic matter digestibility and voluntary food intake (Period I)

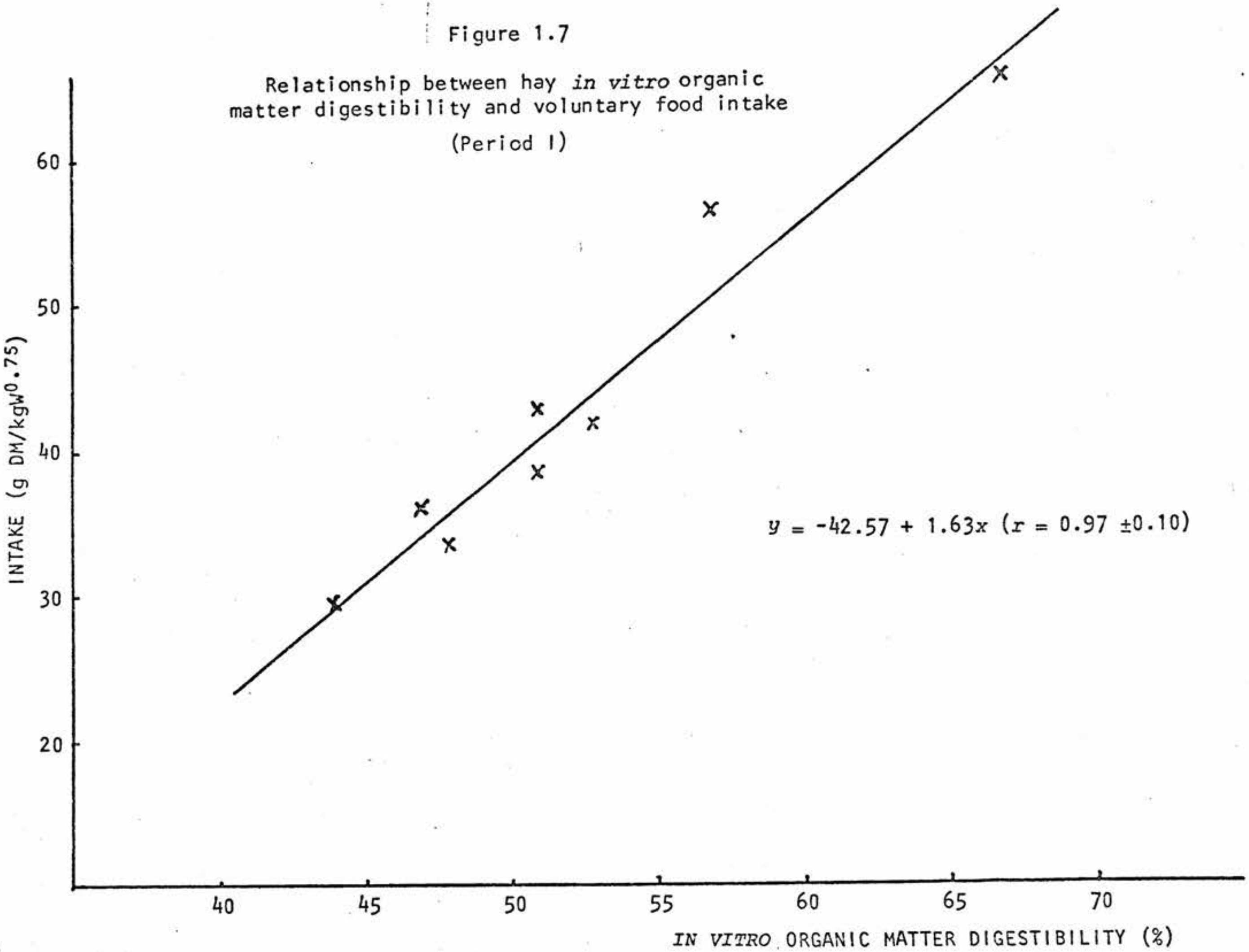


Figure 1.8

Relationship between hay *in vitro* organic matter digestibility and voluntary food intake

(Period II)

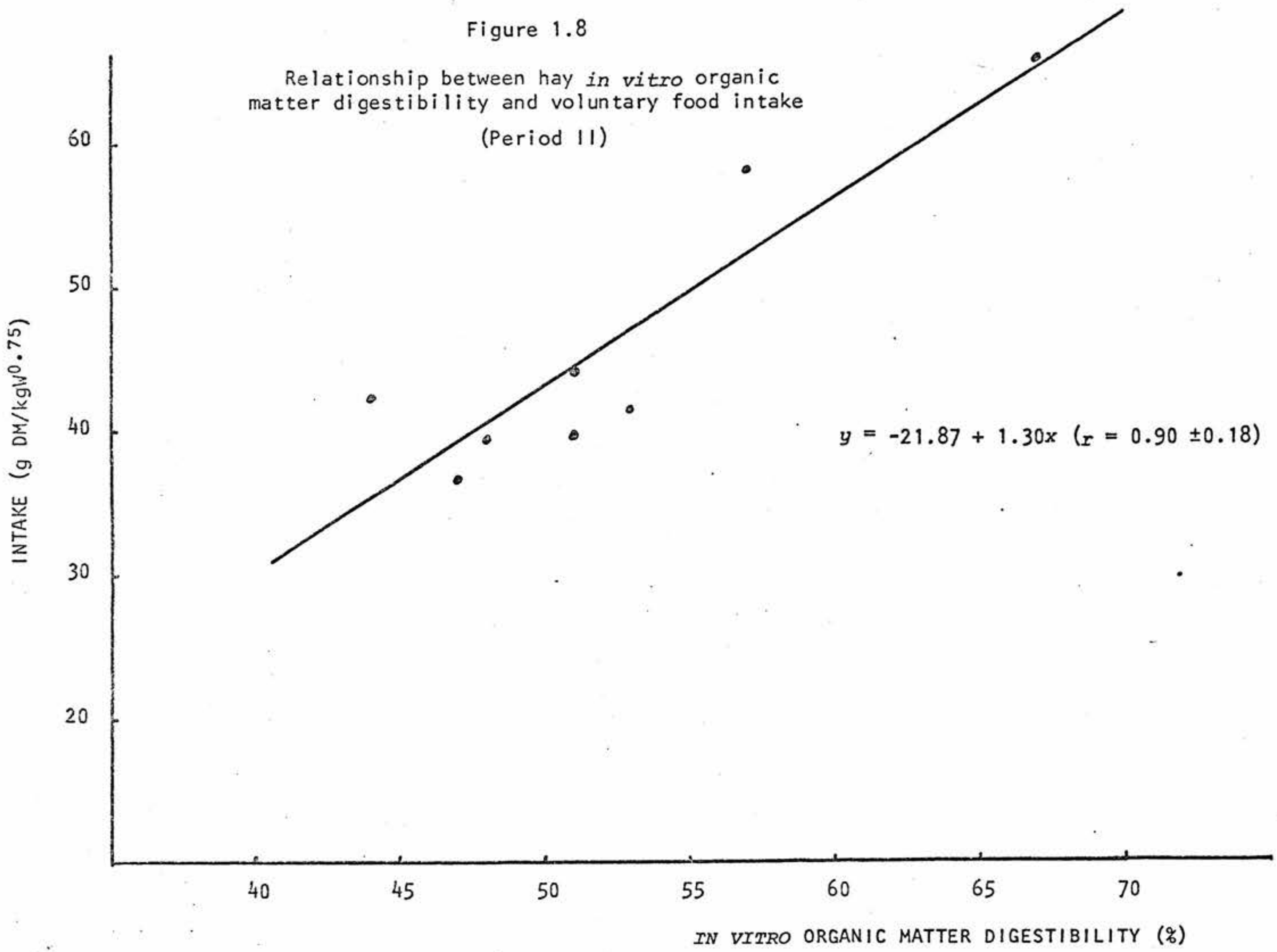
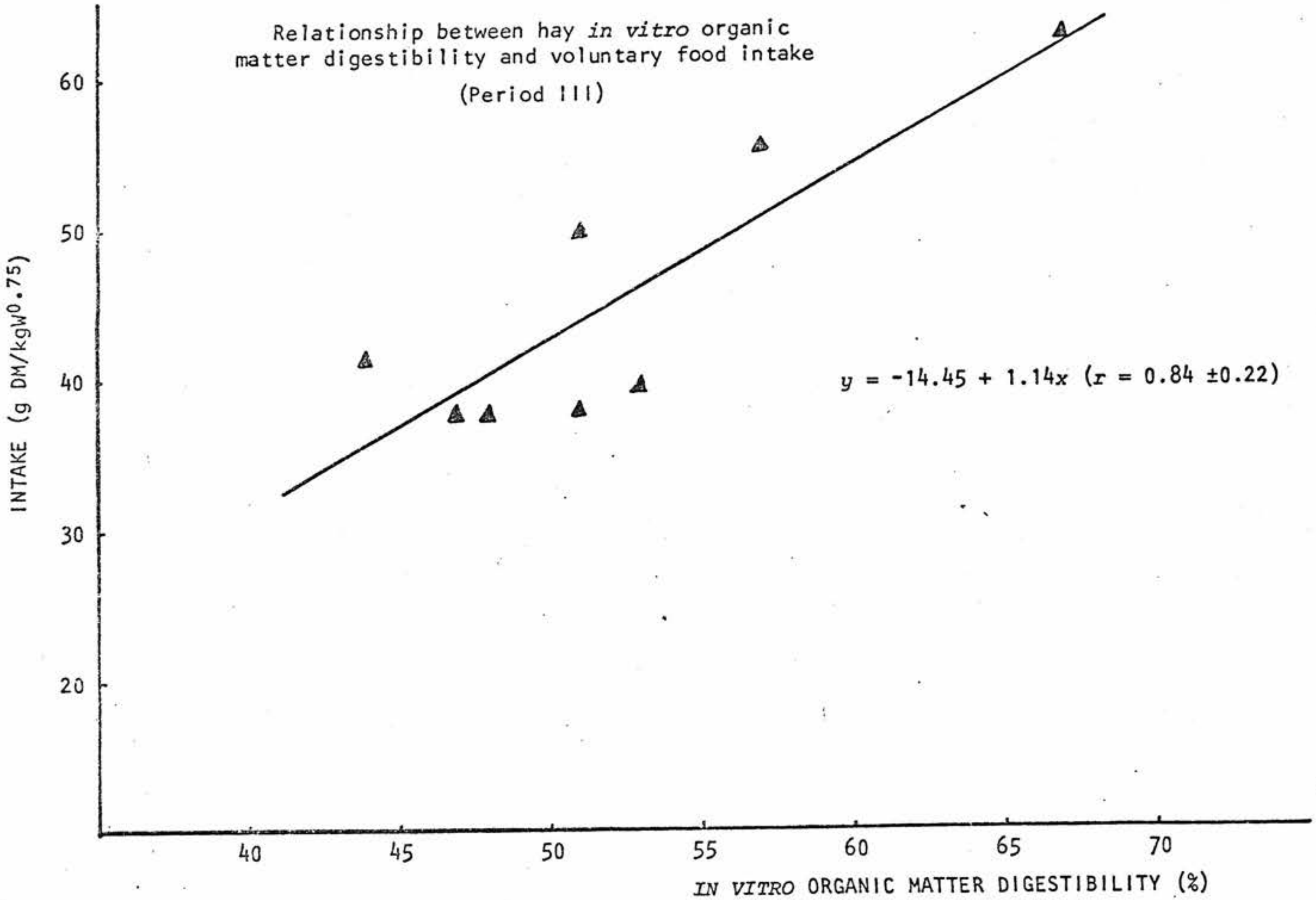


Figure 1.9

Relationship between hay *in vitro* organic matter digestibility and voluntary food intake

(Period III)



Period I $y = -30.26 + 9.20x$ $(r = 0.92 \pm 0.16)$

Period II $y = -8.81 + 6.87x$ $(r = 0.83 \pm 0.22)$

Period III $y = -1.58 + 5.88x$ $(r = 0.76 \pm 0.26)$

where $y$ = g dry matter per kg$W^{0.75}$ (W = weight at 8 weeks pre-parturition)
and $x$ = estimated metabolizable energy in MJ/kg DM

Similar analysis was carried out on the pooled data on the calculated *in vitro* organic matter digestiblity of the hays and the observed intakes of hays by the ewes during the three periods (see Figures 1.7, 1.8 and 1.9). The following expressions of intake and *in vitro* organic matter digestibility were derived:

Period I $y = -42.57 + 1.63x$ $(r = 0.97 \pm 0.10)$

Period II $y = -21.87 + 1.30x$ $(r = 0.90 \pm 0.18)$

Period III $y = -14.45 + 1.14x$ $(r = 0.84 \pm 0.22)$

where $y$ = g dry matter per kg$W^{0.75}$ (W = weight at 8 weeks pre-parturition)
and $x$ = *in vitro* organic matter digestibility of the forage

It is evident that the best prediction of intake at the three periods of late pregnancy examined was given by the *in vitro* organic matter digestibility value. As pregnancy advanced from period I to period III the relationship between hay quality (as measured by digestibility and estimated metabolizable energy) and intake was less definite, probably due to the effects of foetal load and fat reserves upon intake (see page 19).

Fodder quality affected pattern of intake. With hays 3), 4), 7) and 8) [dry matter digestibility $\geq$ 53%] and complete ruminant diet the trend in intake pattern was to decline during the final five weeks of pregnancy. With hays 1), 2) and 5) [dry matter digestibility $\leq$ 52%]

Table 1.3

Ewe body condition score reduction and litter size and weight

| Year | Hay | Litter size | Condition score reduction | Litter weight kg (±SE) |
|---|---|---|---|---|
| 1972 | 1 | 2.0 | 1.0 | 7.23 ±1.6 |
| | 2 | 2.0 | 0.7 | 6.17 ±1.1 |
| 1973 | 3 | 2.0 | 1.3 | 8.36 ±1.1 |
| | 4 | 2.3 | 0.8 | 10.33 ±1.0 |
| | CRD | 2.2 | +0.1 | 10.03 ±1.1 |
| 1974 | 5 | 1.8 | 1.9 | 6.24 ±1.4 |
| | 6 | 2.0 | 1.8 | 6.00 ±1.5 |
| | 7 | 1.5 | 1.5 | 6.50 ±1.4 |
| | 8 | 2.0 | 1.6 | 8.64 ±1.3 |
| | CRD | 2.0 | +0.1 | 10.10 ±1.4 |

forage intake tended to rise during the eight week feeding period (see Figures 1.2 and 1.3).

The reasons for differences in intake pattern are not clear. It was postulated on examining the data obtained in Experiment 1.1, that the increase in intake measured with hays 1) and 2) was due to a decrease in body fat reserves (see Table 1.3) as measured by lumbar palpation (Russel *et al* 1969), but subsequent measurements in Experiments 1.2 and 1.3 indicated that body fat reserves changed by similar, or even greater, amounts, without an increase in voluntary roughage intake during the eight week period (see Table 1.3).

Hay quality not only governs intake of dry matter, but also the better the quality of a forage the greater is the nutrient intake (Blaxter *et al* 1961). Nutrient intake may affect lamb size (see page 51 and the extent to which body reserves in pregnancy are depleted (see page 51). It is suggested that the relative change in reproductive tract volume and fat reserves over the period of the experiment is governed by the forage supplied and, thus, will affect the pattern of intake. Such a theory finds support in the conclusions of Forbes (1968, 1969a, 1970a, 1970b) that fatness and "incompressible" abdominal organs will limit intake in late pregnancy. In the circumstances of feeds of poor quality, fat reserves depletion and the increase in rate of passage of digesta through the digestive tract associated with pregnancy (Graham and Williams 1962; Forbes 1969a, 1971) more than compensate for the increase in reproductive tract volume. When the offered feeds are of superior quality, fat reserves depletion, and the increase in rate of passage may not be sufficient to compensate for the increase in the volume of the products of conception.

Further discussion of the results and implications of the above findings are included in the discussions following experiments reported in Sections II and III when the effects of concentrate upon hay intake, and nutrient ingested are considered.

# SECTION II

## THE EFFECT OF CONCENTRATES UPON THE VOLUNTARY INTAKE OF ROUGHAGES

## The effect of concentrates upon the voluntary intake of roughages

### 1. Review of literature

#### (i) Introduction

It has been shown in Section I that voluntary roughage intake of ewes may decline from the 16th or 17th week of pregnancy, especially in those animals bearing multiple foetuses. At this time nutrient requirement is increasing rapidly as voluntary intake declines (see page 57), and it becomes essential to provide some form of concentrated food containing both energy and nitrogen to compensate for the late pregnancy reduction in roughage intake. The effects of concentrate addition to a roughage diet upon voluntary forage intake, and the causes of any changes brought about by that concentrate addition are important in deciding the quantity and/or constituents of supplement to be offered.

#### (ii) Addition of carbohydrate

Addition of maize starch (Swift, Thacker, Black, Bratzler and James 1947; Head 1953; Kane, Jacobson and Damewood 1956, 1959) and glucose (Hamilton 1942) to a roughage diet has been shown to decrease the digestibility of the fibre fraction, possibly due to the rapid growth of amylolytic bacteria, and the resultant depletion in other essential nutrients (especially nitrogen), consequently depressing cellulytic bacterial activity (El-Shazly, Dehority and Johnson 1961; Blaxter 1962), or the accompanying reduction in rumen pH (Head 1961). The addition of readily available carbohydrate to the rumen microflora does not always reduce roughage fibre digestibility (Beames 1959; Faichney 1965). Kane *et al* (1959) have produced evidence that fibre digestibility is depressed to a lesser degree with rumen acclimatisation, permitting time for the change in the proportions of different rumen micro-organisms with the change of diet (Eadie and Mann 1970; Giesecke 1970).

Since the rate of disappearance of digesta from the rumen effectively governs voluntary roughage intake (see page 8 ) and the addition of carbohydrate reduces fibre digestion, it is to be expected that pure carbohydrate additions to the diet would reduce roughage intake. The limited evidence available shows there is no effect of carbohydrate upon intake of straw (Beames 1959; Coombe and Tribe 1963; Faichney 1965). It is possible that straw palatability, or the lack of some other factor (for example nitrogen) may have limited intake of the straw alone diet, and the addition of carbohydrate had no apparent effect upon intake.

(iii) Addition of nitrogen

Moir and Harris (1962), Elliot and Topps (1963), Elliot (1967) and Weston (1971) have demonstrated that low nitrogen levels in the diet resulted in a reduction in food digestibility, there being a high correlation between food intake and food nitrogen content (Elliot and Topps 1963). However, Head (1953) offering mixtures of hay and concentrates, could not find any effect of nitrogen upon voluntary food intake.

When Campling *et al* (1962) fed restricted amounts of straw, its retention time in the rumen was reduced by urea infusion. Intraruminal infusion with 150 g of urea per day caused a 40% increase in intake of oat straw (Campling *et al* 1962), and Fishwick, Hemingway, Parkins and Ritchie (1973) found intake of low nitrogen oat straw to be increased by up to 20% by giving 165 g crude protein (urea based) to Friesian steers. Similar observations have been made by Lyons, Caffrey and O'Connell (1970) using a protein based concentrate, and Fishwick, Fraser, Hemingway and Parkins (1973) using a molasses and urea supplement. The addition of protein, urea, or urea plus molasses increased the digestibility of dietary dry matter and crude fibre (Akkada and El-Shazly 1958; Beames 1959; Campling *et al* 1962; Coombe and Tribe 1963; Lyons *et al* 1970; Fishwick *et al* 1973), and increased the rate of cellulose disappearance from the rumen (Campling *et al* 1962; Coombe and Tribe 1963) through the stimulation of rumen micro-flora (Bruggemann and Giesecke 1967). Part of the intake response to nitrogen is, therefore, due to an accelerated rate of digestion and the more rapid disappearance of digesta from the reticulorumen. Intake response to nitrogen supplementation is confined to poor quality forages (Campling *et al* 1962), and Campling (1966a) considers that below a crude protein content of 8-10% rate of disappearance of digesta of long forages from the rumen is reduced, and thus voluntary intake is limited.

Different workers suggest different optimal levels of crude protein (CP) in the diet, below which intake is reduced:

| | |
|---|---|
| Head (1953) | 6.2% CP |
| Topps (1962) | 12.5% CP |
| Blaxter and Wilson (1963) | 8.5% CP |
| Campling (1966a) | 8-10.0% CP |
| Weston (1971) | above 11.7% CP |

Circumstances and feeds differed in type and quality in the above work, and it is likely that the optimal level of nitrogen content of feeds will depend upon factors peculiar to a given feed.

Moir and Harris (1962) infused casein into the duodenum of wethers. The intake response measured on poor, low nitrogen oat hay could not be satisfactorily explained by the recycling of nitrogen to the rumen, and a direct effect of nitrogen and nitrogen status on voluntary intake was postulated. The series of experiments by Egan and Moir (1965) and Egan (1965a, 1965b, 1965c) when feeding oat hay of low nitrogen content (0.56 to 0.70% nitrogen) showed that nitrogen status of the body tissue was involved in the intake control of low protein feeds.

(iv) Addition of concentrates

a) Quantitative effects

By increasing the proportion of concentrates in the diet the digestibility of the dry matter of the whole is increased (Blaxter and Wilson 1963; Campling and Murdoch 1966; Murdoch 1967; Robinson and Forbes 1970). Campling (1966c), to shed light upon the control of intake of hay/concentrate mixtures, offered dairy cows *ad libitum* hay with either 0, 2.5, 5.0 or 7.5 kg of a standard concentrate per day. The addition of 2.5 kg of concentrate did not affect voluntary intake of hay, but intake of the forage was reduced by the addition of 5.0 kg of concentrates or more. The ingestion of large amounts of concentrate reduces both the rate of passage of digesta (Eng, Riewe, Craig and Smith 1964; Campling 1966c) and the digestibility of the crude fibre (Campling 1966c). With 7.5 kg of concentrate Campling (1966c) found that the quantity of digesta in the digestive tract of cows at the end of a meal was less than with the lower concentrate levels. The digestibility of the ration dry matter was raised from 67% to 71% by the addition of 7.5 kg of concentrate and it was concluded that digestibility was above the level at which physical regulation of food intake operated.

Freer and Campling (1963) recorded similar observations, and Crabtree and Williams (1971a), working with sheep, found that hay intakes declined as the concentrate level increased. Similar quantitative effects of concentrate upon forage intake have been measured by many other workers (for example Blaxter and Wilson 1963; Campling and Murdoch 1966; Murdoch 1967; Duncan 1973).

b) Qualitative effects

1. Hay quality

Summarizing early American work on the addition of concentrates to roughage diets Reid (1956) concluded that the reduction in the intake of roughage when concentrates were given to cows seemed to be less marked with high quality than with low quality roughages. Similar conclusions were drawn by Holmes and McCluskey (1955) when reviewing early British experiments. More recent work by Blaxter, Wainman and Wilson (1961), Blaxter and Wilson (1963), Holmes, Jones, Drake-Brockman and White (1965), Campling and Murdoch (1966), Murdoch (1967) and Leaver (1973), however, shows that the higher the quality of the roughage the greater the depression of intake when concentrates are offered.

Blaxter and Wilson (1963) fed wethers to appetite on three hays of different quality (of metabolizable energy values of 10.25$^{(1)}$, 9.45$^{(2)}$ and 9.04$^{(3)}$ MJ per kg dry matter: measured at maintenance level) plus 0, 200, 500, 800 or 1200 g of pelleted concentrate. The voluntary intake of hays when offered as sole food was 70, 62 and 57 g per kg$W^{0.73}$ for the three hays respectively. When concentrates were given in increasing amounts, the intakes of hays$^{(2)}$ and $^{(3)}$ increased to maxima of 65 and 64 g per kg$W^{0.73}$ respectively and thereafter declined, while with hay$^{(1)}$ intake declined with even the smallest intake of concentrate.

The data of Murdoch (1964), Campling and Murdoch (1966) and Murdoch (1967) give similar results, but Murdoch (1967) found that the replacement values of concentrates for hays of high quality were not as large as those of Blaxter and Wilson (1963). The experiments of Campling and Murdoch (1966) and Crabtree and Williams (1971a) further emphasise the interaction between forage quality and the addition of concentrates. Four kilograms of concentrate caused little change of intake, and a small increase in the intake by cows of barley straw, but six or eight kilograms of concentrate reduced hay intake, while the intake of straw was unaffected (Campling and Murdoch 1966). Crabtree and Williams (1971a), working with sheep, found that straw intake increased until the concentrate was 25% of the total diet and thereafter declined, while hay intakes declined as concentrate level increased. The better the forage quality the greater was the concentrate replacement value.

When wether sheep were fed on poor hays to appetite plus 275, 550 or 825 g of barley, Lamb (personal communication) found that intake response was variable, and concluded that the effect of barley on intake was dependent upon the nitrogen content of the forage, for the greater the nitrogen content of the hay the less was the depression of hay intake on addition of barley.

2. Concentrate quality

Murdoch (1964) has demonstrated that additional barley (12.3% crude protein) depressed intake of hay by sheep to a greater extent than dairy cubes (18.8% crude protein). Observations on the effect of barley, and barley plus groundnut upon the intake of silage indicated that the mixed concentrate had a less depressing effect upon intake (Murdoch 1962), probably because of the higher nitrogen content of the mixed concentrate. Similarly, Campling and Murdoch (1966) found with dairy cows that when an *ad libitum* hay diet was supplemented with one kilogram of either mixed concentrates (19.5% crude protein) or rolled oats, or flaked maize, hay intake was depressed by 0.29, 0.37 or 0.45 kg of dry matter respectively. The work of Lyons *et al* (1970) demonstrated that when offering concentrates of increasing crude protein content to steers fed on *ad libitum* straw, intake was increased by 1.37 kg of concentrate containing 13.6% crude protein, but above this level of crude protein no increase in intake was observed. Andrews, Escuder-Volonte, Curran and Holmes (1972) found that as the energy concentration of low protein barley straw diets (≤6.6% crude protein) was improved by energy supplementation, straw intake by cattle was reduced, but when the protein concentration was raised energy supplements did not affect intake.

Crabtree and Williams (1971b) offered mixtures of barley and soya-bean in various ratios plus *ad libitum* hay to sheep, and showed that when barley was not given, soyabean meal, added at 25% of the hay dry matter intake, caused an increase in hay dry matter consumption from 287 to 412 g per day. Hay intake was depressed to 339 g per day by increasing soyabean meal to 50% of intake of hay dry matter. When barley was given soyabean meal did not affect hay intake. In general it was found that an increase in concentrate allowance (barley + soyabean) reduced hay intake, whereas an increase in the crude protein content of concentrate increased hay intake.

(v) Summary and conclusions

Addition of carbohydrate alone to a roughage diet may reduce forage intake, while the addition of nitrogen may cause an increase of forage intake, especially in the case of poor quality roughage. Responses to dietary additions of concentrates may be considered in relation to their energy and crude protein content. Nitrogen supplements may partially, or completely alleviate the depression effect of carbohydrate upon intake through maintenance of cellulose digestibility.

The effect of additional energy and/or nitrogen to the diet is variable, and it would appear dependent upon the level of readily available nutrients in the roughage, whether carbohydrate or nitrogenous. The relative proportions of protein to energy and the quality of the roughage being supplemented will govern the extent and nature of the responses to a given concentrate. The poorer the forage the less is the depression effect of concentrate upon forage intake, and the greater the response in increasing the total dry matter ingested, while conversely, the better the forage the greater is the substitution value of concentrate for hay and there is a smaller or no increase in total dry matter consumed. When the basal forage is of poor quality the concentrate should have a higher nitrogen content.

## 2. Intake of forage/concentrate mixtures

### Experimental report

### (i) Introduction

In Section I it has been demonstrated that hay quality effectively governed intake of forage dry matter by ewes in late pregnancy. Reviewing the literature on the subject of concentrate addition to roughage diets permits the conclusion that the effect on intake of forage by the addition of a standard concentrate is also dependent upon roughage quality. However, the literature does not contain comprehensive reports of investigations on the effect on intake of concentrate additions to forage diets when offered *ad libitum* to ewes during the final weeks of pregnancy.

To obtain information on the relative proportions of forage and concentrates consumed by ewes in late pregnancy, and thus permit the calculation of the potential nutrient intake derived from these mixtures (see Section III) a series of feeding trials was carried out on a range of hay qualities when offered to appetite in conjunction with a standard cereal based concentrate.

### (ii) Materials and methods

Animals, housing, management and hays examined have already been described for the first set of investigations. A standard, pelleted concentrate containing 83.75% barley, 10% soyabean meal, 5% molassine meal, and 1.25% mineral and vitamin supplement, with estimated metabolizable energy and crude protein values of 12.3 MJ per kilogram of dry matter and 14% respectively was used. The model of experimental design indicates the diets at the various stages in pregnancy resulting from the addition of concentrates:

| Period | I | II | III | Total concentrate (kg fresh weight) |
|---|---|---|---|---|
| Days pre-parturition | 56-40 | 39-23 | 22-0 | 56-0 |
| | 150 | 450 | 900 | 30 |
| Hay *ad libitum* | 100 | 300 | 600 | 20 |
| plus | 50 | 150 | 300 | 10 |
| | 0 | 0 | 0 | 0 |

so that for example, a ewe offered hay to appetite plus a total of 30 kg of concentrate received 150 g of concentrate per day in period I, 450 g per day in period II, and 900 g per day in period III. The concentrate level was increased in this stepwise manner to match the pattern of nutrient requirement of the pregnant ewe (see page 58).

The whole of the concentrate fraction of the diet was offered before 08:00 hours. The hays were chopped, and weighed into two kilogram lots; feed boxes were filled after concentrate feeding and replenished at noon and at 17:00 hours. The quantity of hay offered was recorded and refusals bulked and weighed twice weekly. Daily intake of hays was determined, and the total dry matter intake per kilogram of bodyweight$^{0.75}$ calculated for the three periods.

Dietary energy and dry matter digestibility of the mixtures of hay and concentrate offered in Experiments 2.1 and 2.2 were determined by means of offering pregnant ewes similar rations, or by offering wethers the feeds in the proportions eaten by the ewes on experiment. Metabolism cages, similar to those described by McDonald, Edwards and Greenhalgh (1973), were used.

Statistical techniques similar to those described above were used for data analyses.

Figure 2.1

Effect of concentrate upon voluntary intake of hay 1)

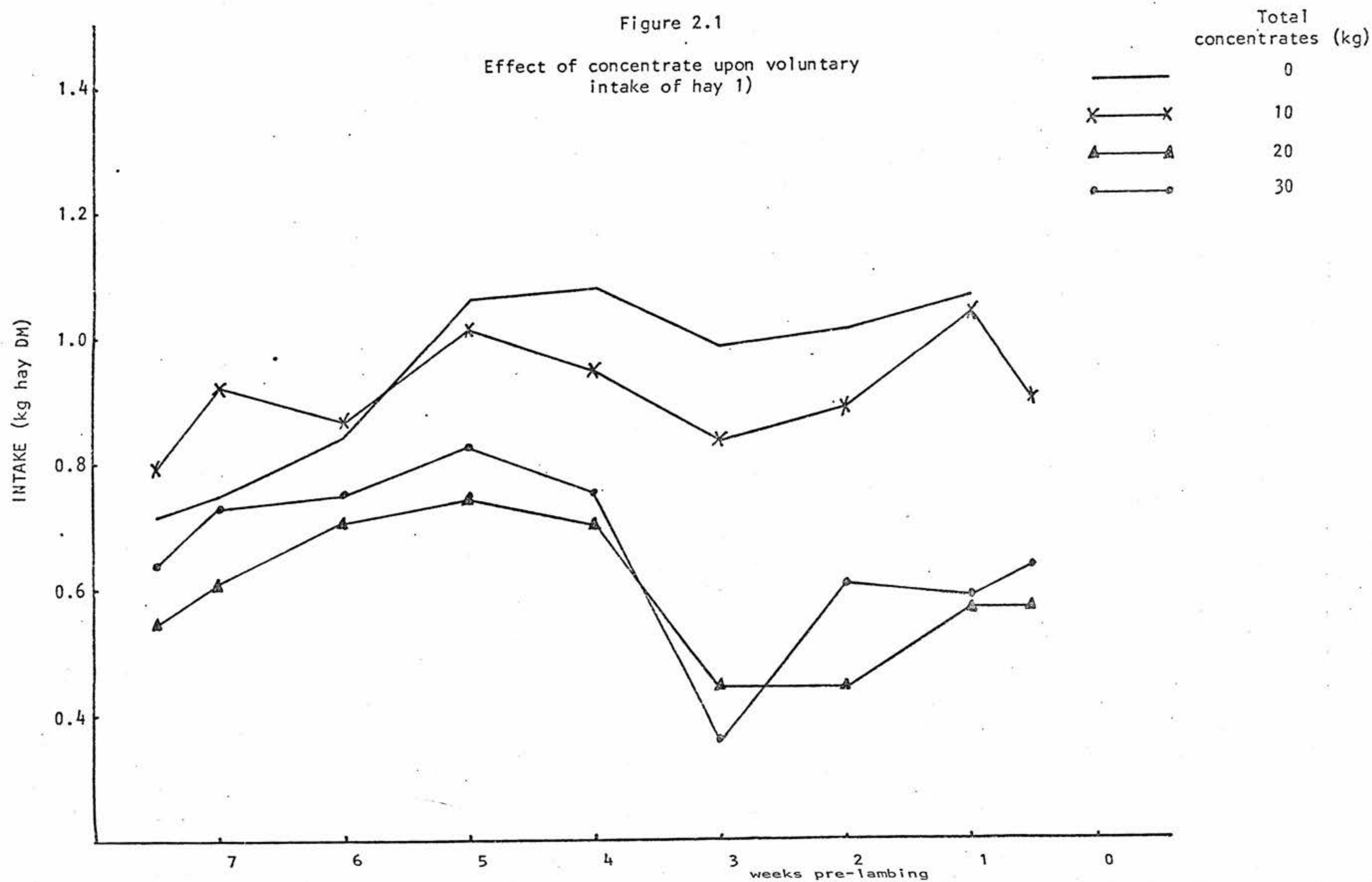


Figure 2.2

Effect of concentrate upon voluntary intake of hay 2)

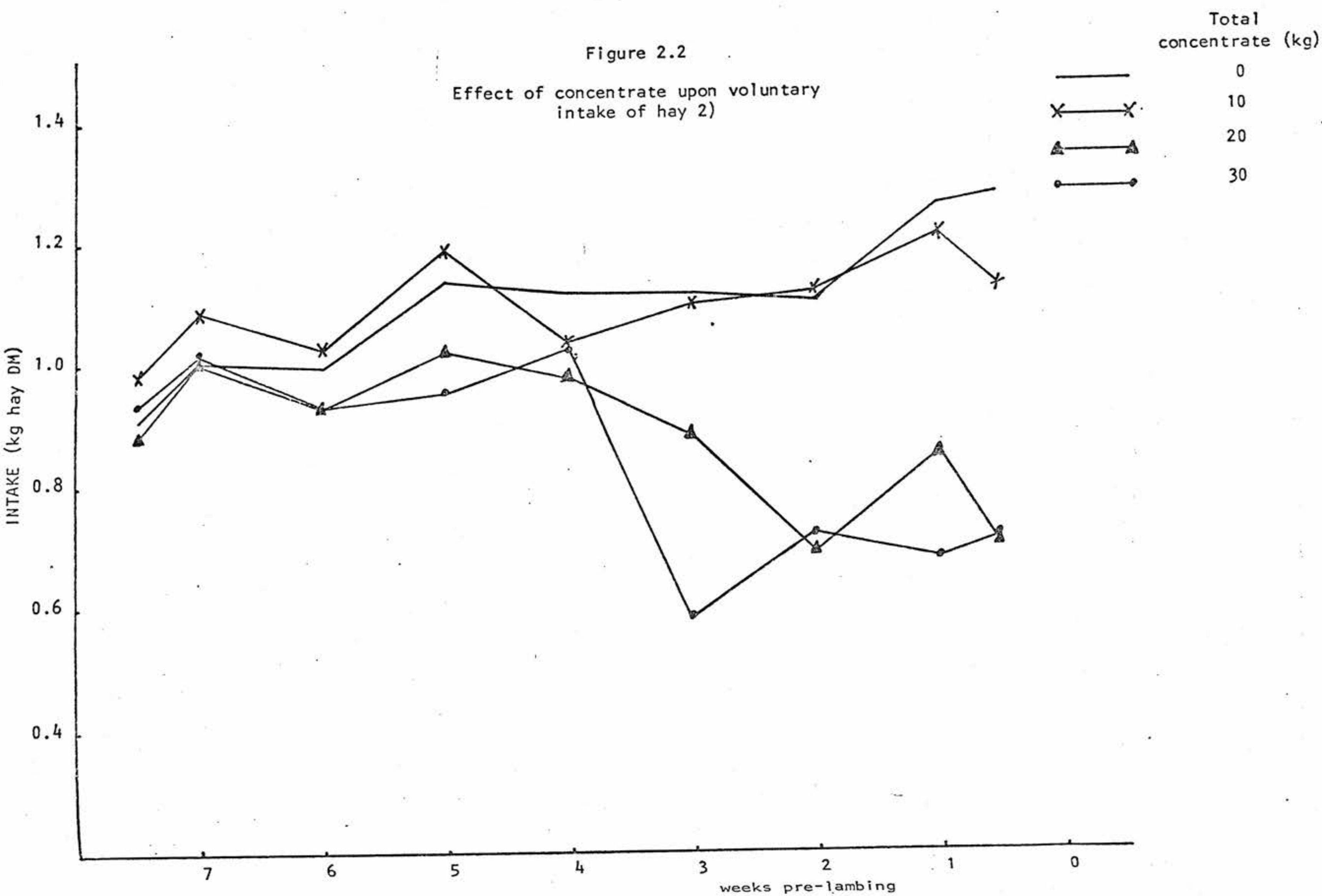


Figure 2.3

Effect of concentrate upon voluntary intake of hay 3)

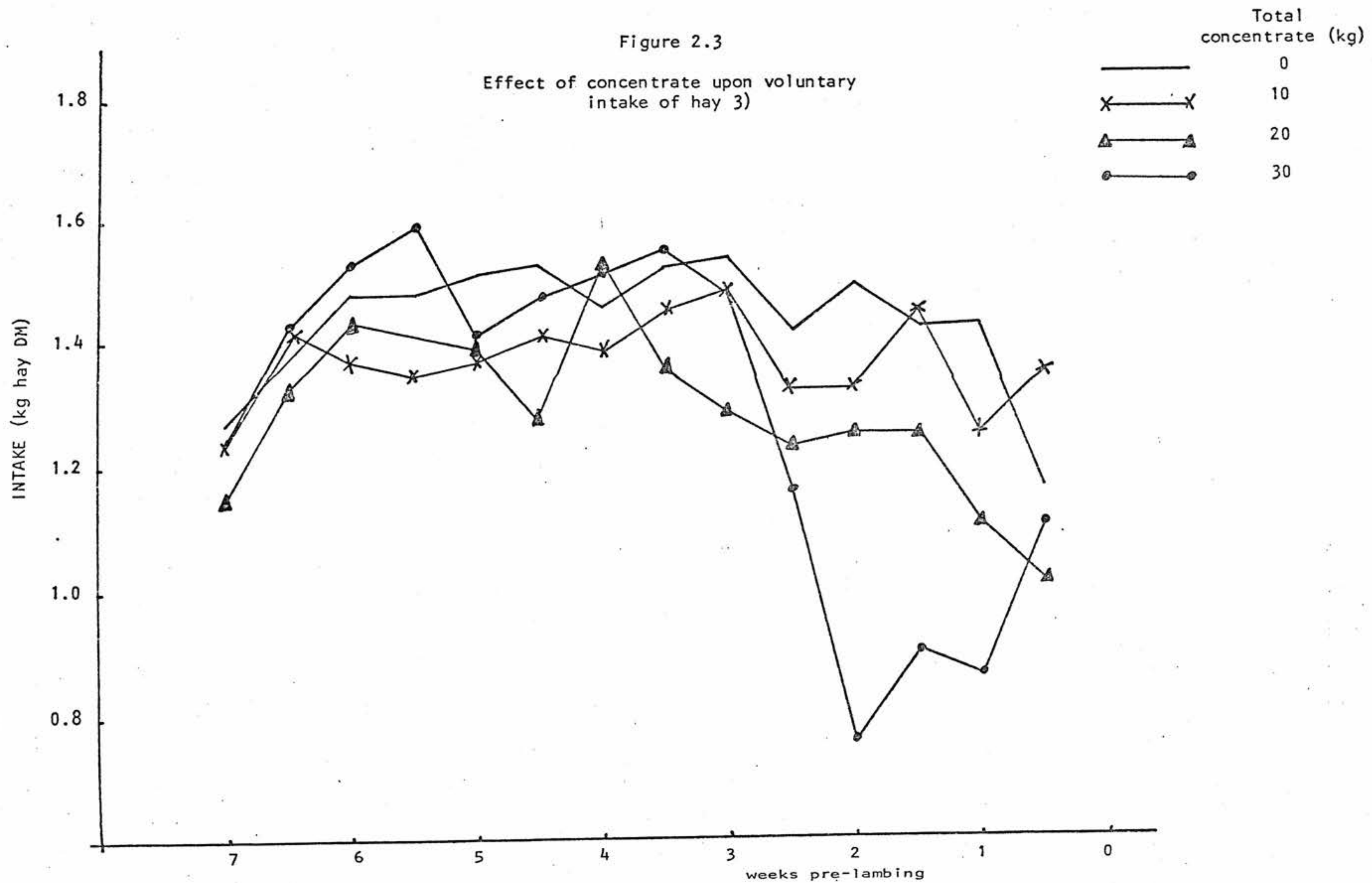
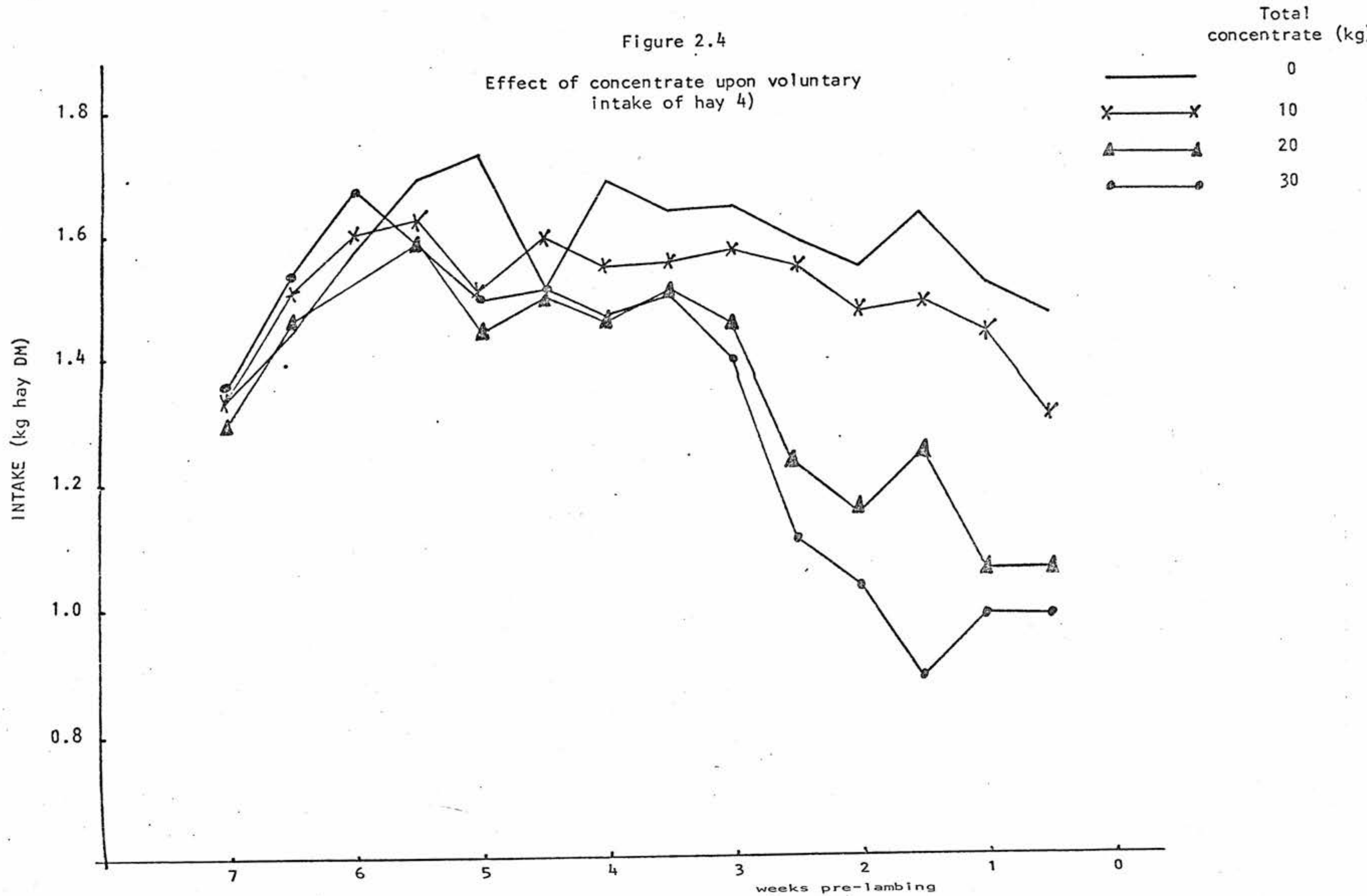


Figure 2.4

Effect of concentrate upon voluntary intake of hay 4)



(iii) Results

Experiment 2.1

The relatively poor quality hays 1) and 2) were offered to appetite plus one of the four levels of concentrate to four ewes per diet in periods I, II and III. Patterns of intake of ewes on both hays were similar at each level of concentrate offered. Figures 2.1 and 2.2 indicate the effect of concentrates upon the intake of hays 1) and 2) respectively. It was not until the concentrate levels were in excess of 300 g per day that hay intake declined, and was only significantly ($P<0.05$) reduced when 600 g, or more, were on offer. Offering 600 g or 900 g of concentrate per day caused a sharp decrease in hay intake, followed by a gradual increase until lambing.

The higher the level of concentrate offered, the greater was the dry matter ingested (see Table 2.1) both within and between the three periods considered, with the exception of ewes offered hay 1) plus a total of 20 kg of concentrate. Digestibility of the energy and the dry matter of the diet increased with an increase in the quantity of concentrate offered (see Table 2.2). The data, when adjusted by covariance, suggested that voluntary intake was affected by foetal number and weight of lamb produced, but failed to achieve significance at the $P<0.05$ level. Multiple bearing ewes consumed less than single bearing ewes. Seven ewes produced single lambs and six produced triplets. The remainder produced twins.

Experiment 2.2

Further investigations of the effect of level of concentrate upon hay intake were carried out in a similar manner with hay 3) and hay 4) plus the four levels of concentrate being offered to six ewes. The addition of concentrate affected the intake of both hays in a similar manner (see Figures 2.3 and 2.4), and it was not until more than

Figure 2.5

Effect of concentrate upon voluntary intake of hay 5)

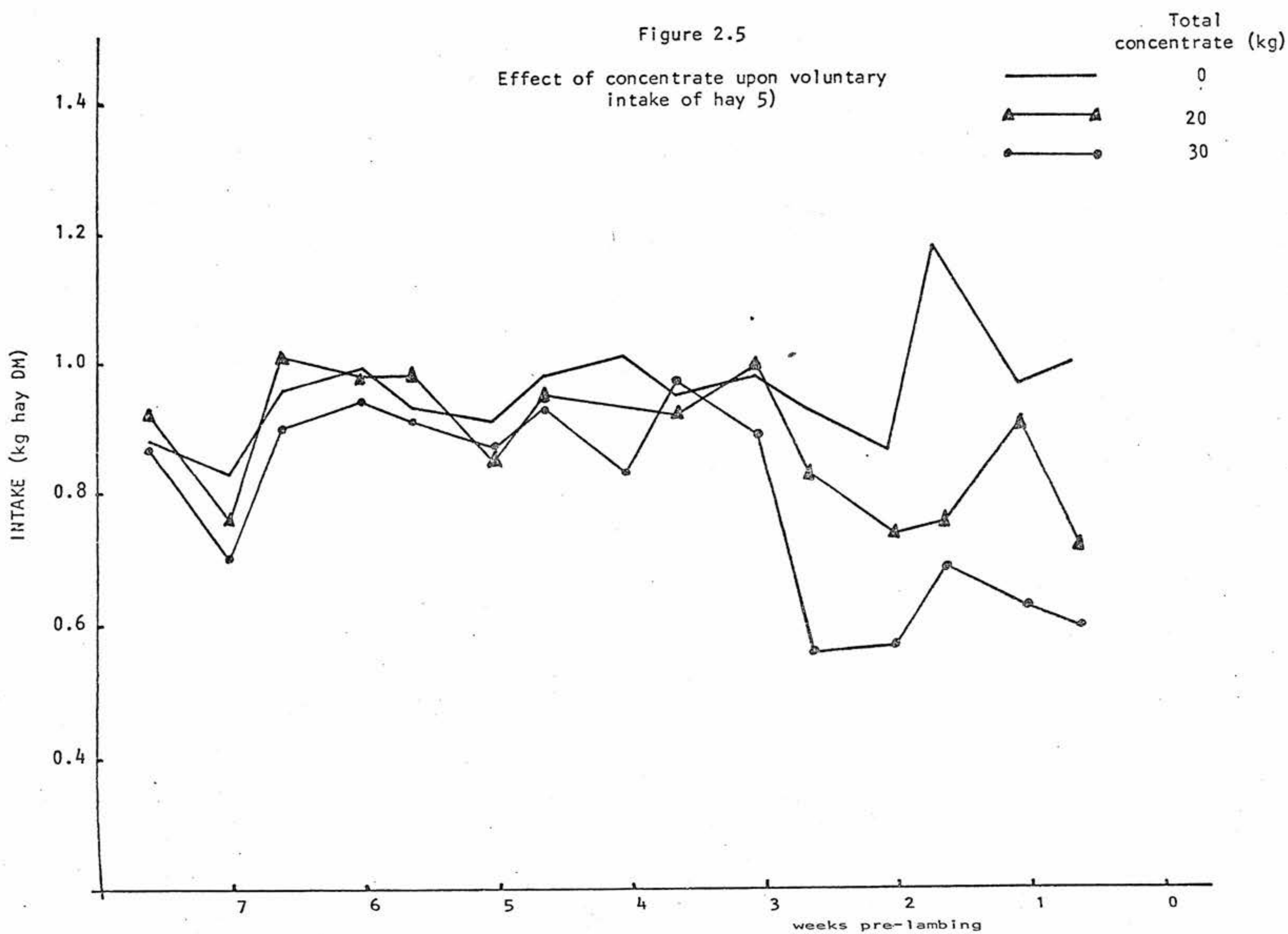


Figure 2.6

Effect of concentrate upon voluntary intake of hay 6)

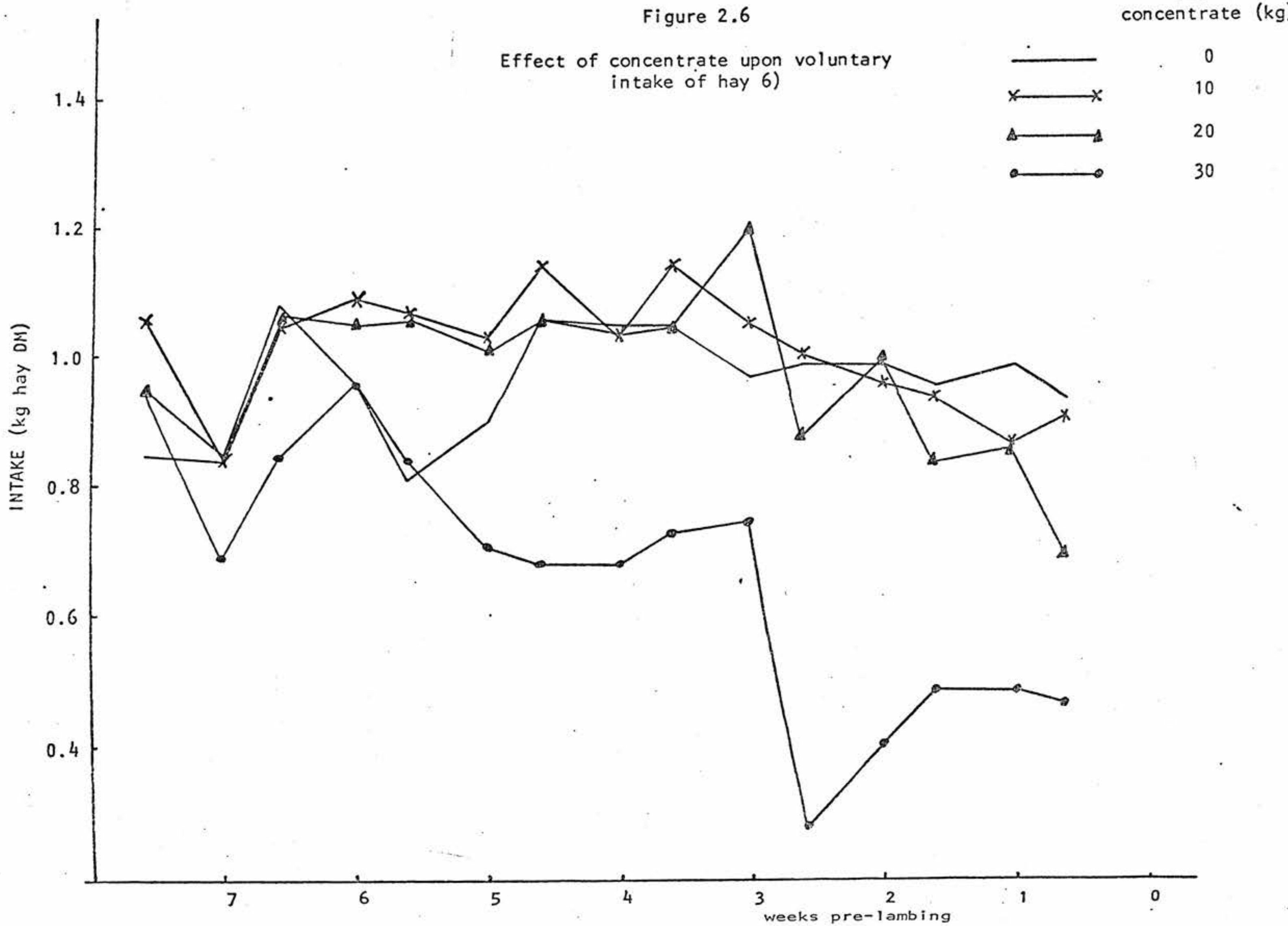


Figure 2.7

Effect of concentrate upon voluntary intake of hay 7)

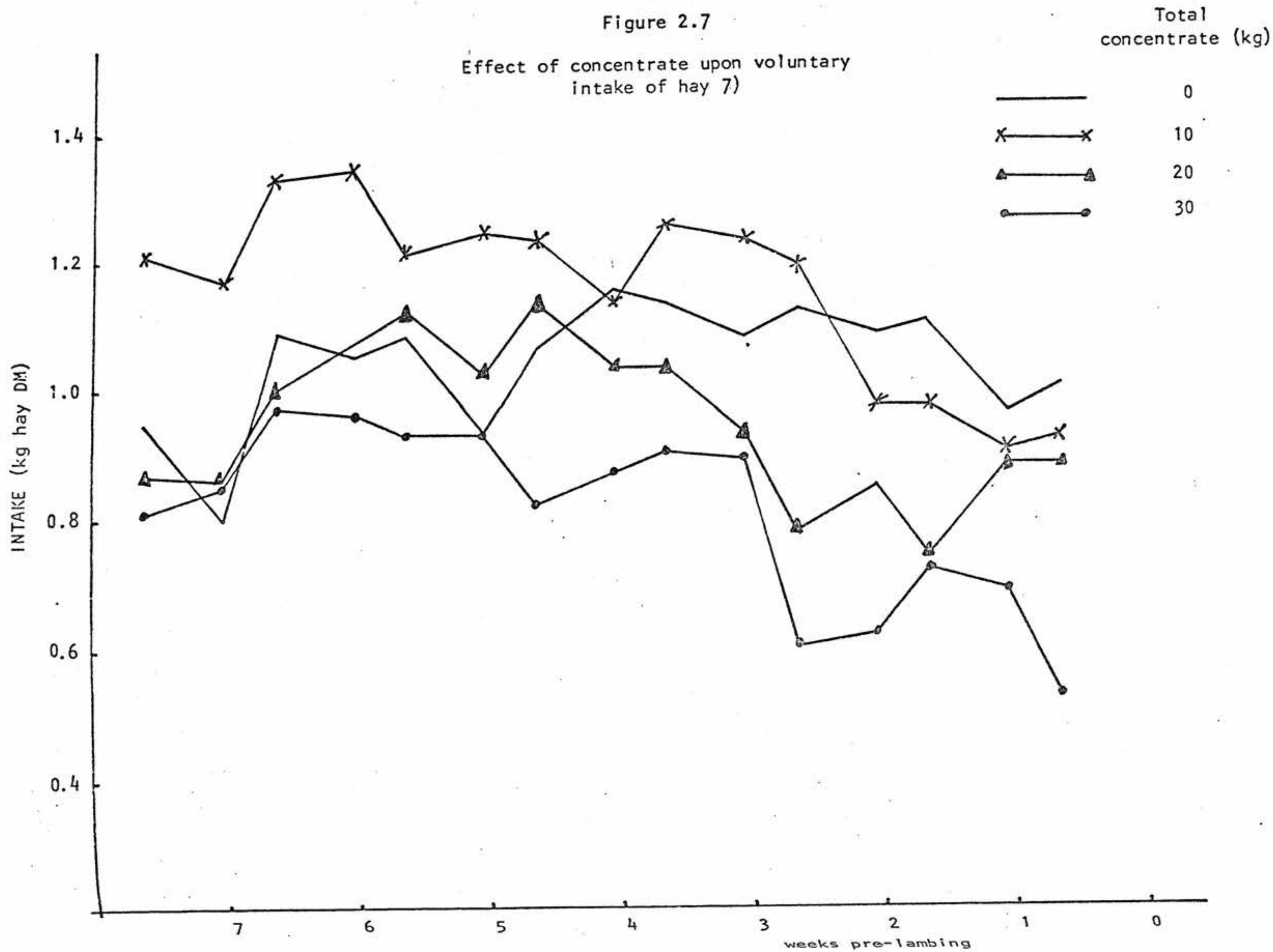
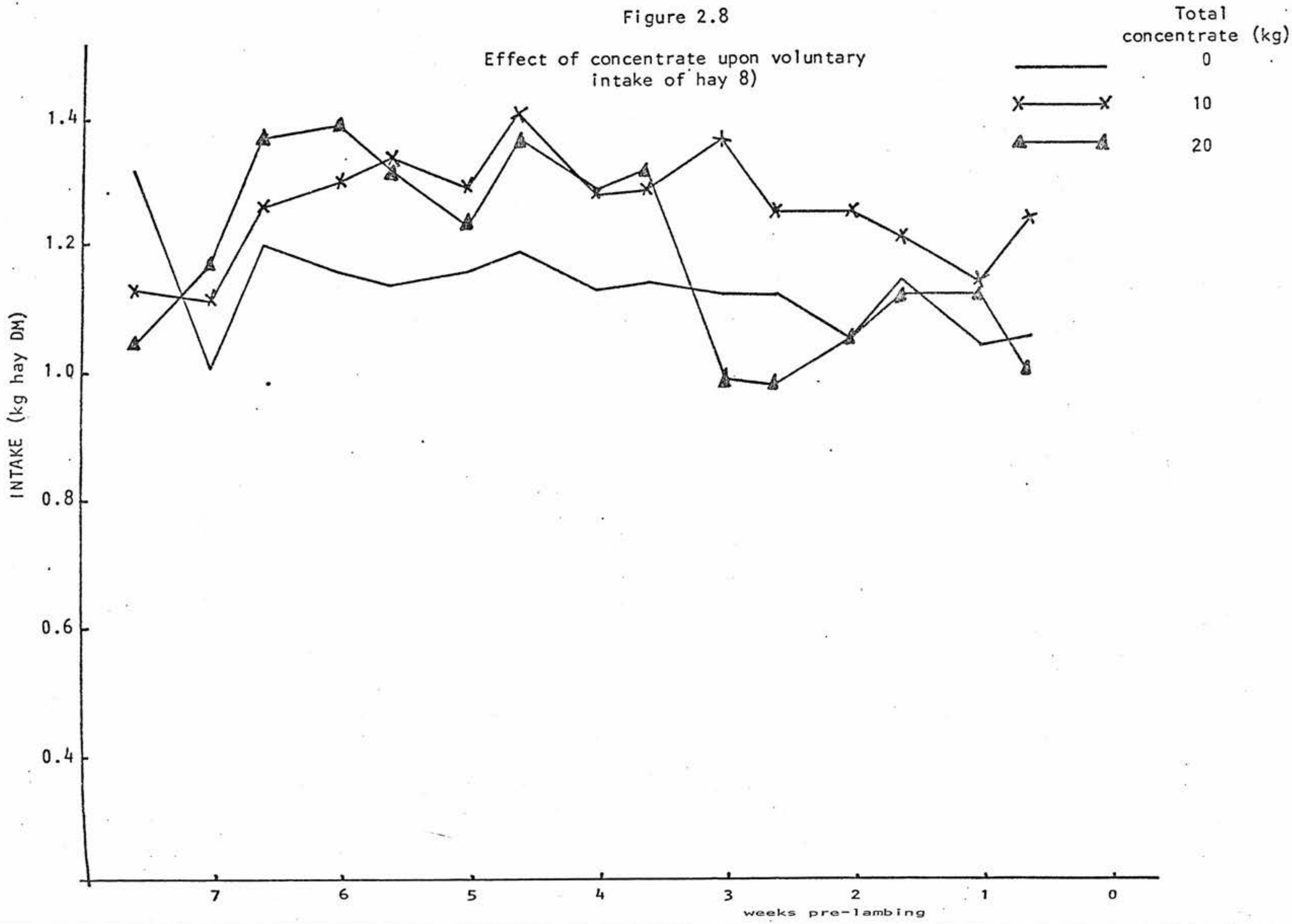


Figure 2.8

Effect of concentrate upon voluntary intake of hay 8)



300 g of concentrate per day were on offer that hay intake was reduced. Differences in hay intake caused by the addition of concentrates did not achieve significance (P<0.01) until 900 or 600 g of concentrate were on offer for hays 3) and 4) respectively. Six hundred and 900 g of concentrate caused a sharp reduction in voluntary hay intake, followed by a partial recovery over the following two weeks.

Total dry matter intake increased as the quantity of concentrate offered was raised, but with hay 4) voluntary intake in period III was not increased by the addition of more than 300 g of concentrate. Digestibility of the total energy and dry matter of the diet was improved as the level of concentrate increased (see Table 2.2). Adjustment of the intake data by covariance again indicated non-significant effects of litter size and weight upon voluntary food intake, the single carrying ewes consuming more than their multiple bearing counterparts. Six ewes produced single lambs and 16 produced triplets while the remainder produced twins.

Experiment 2.3

The concentrate effect upon hay and total dry matter intake was further investigated in 1974 with four ewes per diet using hays 5), 6), 7) and 8). The 10 kg and 30 kg levels of concentrate were omitted from the tests of hays 5) and 8) respectively. Concentrate addition had similar effects upon intake of each hay (see Figures 2.5, 2.6, 2.7 and 2.8), with the total dry matter ingested increasing with the amount of concentrate offered (see Table 2.1). The quantity of hay consumed was not affected until the concentrate level exceeded 300 g per day. Significant differences in hay intake due to concentrate level were not achieved with hays 7) or 8), and 900 g of concentrate per day were required to significantly (P<0.01) reduce intakes of hays 5) and 6).

The addition of 600 or 900 g of concentrate per day caused initially sharp reductions in voluntary hay intake, followed by a partial recovery until parturition (see Figures 2.5, 2.6, 2.7 and 2.8). Adjustment of the data by covariance confirmed the previous observations of the effect of litter size and weight upon voluntary intake. The differences in intake due to litter size in period III achieved significance ($P<0.05$), twin bearing ewes consuming on average 136 g dry matter less than their single bearing experimental mates. Ten ewes on experiment produced single lambs, twelve produced triplets and the remainder produced twin lambs.

(iv) Discussion and conclusions

The substitution effect of concentrates for hay cannot be accurately estimated because of the dynamic physical and/or physiological effects of pregnancy upon intake (Forbes 1970a, 1970b, 1971), although it is evident that the addition of more than 300 g of concentrate (fresh weight) will cause a reduction in voluntary roughage intake. Duncan (1973) found that 300 g (fresh weight) of the same concentrate per day did not affect hay intake of pregnant ewes, but caused non-significant reductions in hay intake when 400 g (fresh weight) of concentrate were on offer. Working with pregnant ewes fed on silage, Sheehan and Lawlor (1972) found that when similar concentrates were offered at 282 g dry matter per day, roughage intake was not reduced. It may be concluded that the addition of up to 300 g of concentrate per day is unlikely to affect the intake of forage by pregnant sheep. Reduction of voluntary roughage intake associated with the addition of more than 300 g of concentrate suggests that to make the best possible use of the available forage and achieve maximum possible nutrient intake from forage, no more than 300 g of concentrate should be supplied. The implications of this are discussed below.

Table 2.1

Total dry matter intake (g per kg$W^{0.75}$ ±SE) by pregnant ewes at three stages during the final weeks of gestation (W = weight at housing)

| Period | | I | II | III | |
|---|---|---|---|---|---|
| Hay | Concentrate | 6 weeks pre-lambing | 4 weeks pre-lambing | 1 week pre-lambing | $W_p^{0.75}$ = weight at 24 hours *post partum* |
| 1 | 30 | 34.0 ±2.11 | 45.3 ± 3.92 | 54.1 ±2.91 | 57.0 |
| | 20 | 26.9 ±2.13 | 37.5 ± 4.72 | 42.3 ±3.06 | 48.1 |
| | 10 | 38.4 ±2.27 | 43.6 ± 2.00 | 51.7 ±3.48 | 60.7 |
| | 0 | 29.5 ±4.08 | 42.2 ± 5.93 | 41.6 ±5.39 | 49.5 |
| 2 | 30 | 46.9 ±2.38 | 57.5 ± 2.66 | 59.8 ±2.04 | 61.8 |
| | 20 | 46.1 ±2.69 | 52.4 ± 2.46 | 58.2 ±5.33 | 61.2 |
| | 10 | 45.9 ±1.60 | 47.1 ± 0.65 | 59.2 ±3.00 | 62.6 |
| | 0 | 42.8 ±3.12 | 44.0 ± 2.58 | 49.9 ±3.31 | 54.4 |
| 3 | 30 | 64.9 ±3.06 | 73.4 ± 2.71 | 64.5 ±3.30 | 63.4 |
| | 20 | 57.8 ±3.11 | 63.2 ± 3.64 | 65.6 ±4.81 | 65.2 |
| | 10 | 54.7 ±2.66 | 61.9 ± 4.20 | 62.6 ±3.68 | 64.5 |
| | 0 | 56.2 ±3.28 | 58.1 ± 2.23 | 55.3 ±2.00 | 58.7 |
| 4 | 30 | 69.2 ±4.72 | 72.8 ± 5.02 | 67.0 ±4.55 | 65.3 |
| | 20 | 66.0 ±3.39 | 69.2 ± 4.82 | 66.9 ±5.46 | 64.9 |
| | 10 | 66.3 ±2.49 | 67.3 ± 1.78 | 68.8 ±3.15 | 69.9 |
| | 0 | 65.1 ±2.84 | 65.7 ± 2.90 | 62.8 ±4.93 | 64.0 |

| | | | | | |
|---|---|---|---|---|---|
| CRD | | 95.6 ±5.00 | 86.7 ± 7.69 | 89.7 ±5.81 | 85.1 |
| 5 | 30 | 38.9 ±5.16 | 47.3 ± 4.57 | 52.8 ±3.20 | 55.3 |
| | 20 | 39.0 ±4.64 | 44.5 ± 4.63 | 49.7 ±5.22 | 54.5 |
| | 0 | 35.8 ±3.33 | 36.8 ± 4.82 | 37.9 ±7.74 | 45.5 |
| 6 | 30 | 38.1 ±3.41 | 41.3 ± 5.22 | 46.9 ±2.17 | 49.6 |
| | 20 | 41.8 ±1.54 | 49.8 ± 2.21 | 50.1 ±2.32 | 53.8 |
| | 10 | 41.2 ±2.27 | 44.6 ± 5.59 | 43.0 ±5.94 | 47.8 |
| | 0 | 33.3 ±0.81 | 39.1 ± 5.49 | 37.3 ±3.88 | 42.1 |
| 7 | 30 | 39.7 ±2.20 | 47.2 ± 2.72 | 54.1 ±3.46 | 56.1 |
| | 20 | 44.3 ±4.72 | 47.3 ± 5.03 | 49.6 ±3.31 | 53.2 |
| | 10 | 48.8 ±5.19 | 49.3 ± 7.53 | 44.1 ±8.03 | 47.5 |
| | 0 | 38.2 ±2.90 | 39.8 ± 4.69 | 37.5 ±2.26 | 41.2 |
| 8 | 20 | 51.2 ±6.14 | 52.6 ± 8.32 | 60.2 ±6.61 | 62.1 |
| | 10 | 50.4 ±2.74 | 53.9 ± 4.51 | 53.1 ±2.27 | 58.4 |
| | 0 | 41.6 ±1.62 | 41.4 ± 2.02 | 39.4 ±3.14 | 44.0 |
| CRD | | 97.1 ±4.63 | 87.1 ±12.29 | 79.1 ±3.74 | 74.60 |

Table 2.2

*In vivo* digestibility of energy and dry matter of hay and concentrate mixtures (hay to appetite)

| Concentrate (g) fresh weight | Hay 1 | | Hay 2 | | Hay 3 | | Hay 4 | |
|---|---|---|---|---|---|---|---|---|
| | energy | DM | energy | DM | energy | DM | energy | DM |
| 0 | 44* | - | 51 | 52 | 59 | 62 | 64 | 67 |
| 50 | 41 | 38 | 51 | 50 | 58 | 61 | 66 | 69 |
| 100 | 44 | 42 | 53 | 52 | 64 | 66 | 62 | 65 |
| 150 | 46 | 44 | 52 | 47 | 64 | 64 | 62 | 65 |
| 300 | 54 | 52 | 57 | 57 | 63 | 65 | 71 | 74 |
| 450 | 56 | 53 | 58 | 57 | 66 | 68 | 69 | 71 |
| 600 | 61 | 59 | 58 | 55 | 68 | 70 | 71 | 73 |
| 900 | 59 | 57 | 64 | 62 | 70 | 72 | 74 | 76 |

*organic matter

Addition of 900 g of concentrate reduced hay intake by between 300 and 600 g per day, but did not appear to be related to the hay quality as observed by Blaxter and Wilson (1963), Murdoch (1964), Campling and Murdoch (1966) and Murdoch (1967). As reported by several workers (e.g. Blaxter and Wilson 1963; Sheehan and Lawlor 1972; Duncan 1973) concentrate addition increased the total dry matter consumed, but when hay 4) is considered, the offering of more than 300 g of concentrate in period III tended to reduce total dry matter intake, possibly because ration energy and dry matter digestibility was greater than 70% (Donefer *et al* 1960; Blaxter *et al* 1961; Hutton 1962a, 1962b; Harris and Raymond 1963; Murdoch 1967). There is no apparent explanation for the discrepancy observed with ewes offered hay 1) plus a total of 20 kg of concentrate.

As the level of concentrate in the diet increased digestibility of the dietary energy and dry matter was improved, with a greater benefit of increased digestibility with hays of poorer quality (see Table 2.2). Similar observations are reported by Blaxter and Wilson (1963), Campling and Murdoch (1966) and Robinson and Forbes (1970). Pooling intake and digestibility data for the three years of experiments demonstrated a relationship between voluntary intake and digestibility similar to that described by Blaxter *et al* (1961) and Murdoch (1967). Intake expressed as grams dry matter per kilogram of bodyweight$^{0.75}$ were much lower than those reported by Blaxter *et al* (1961).

The pooled data for each period were subjected to regression analysis, and equations expressing the relationship between voluntary intake and energy digestibility derived.

Figure 2.9

Relationship between food energy digestibility and voluntary food intake (Period I)

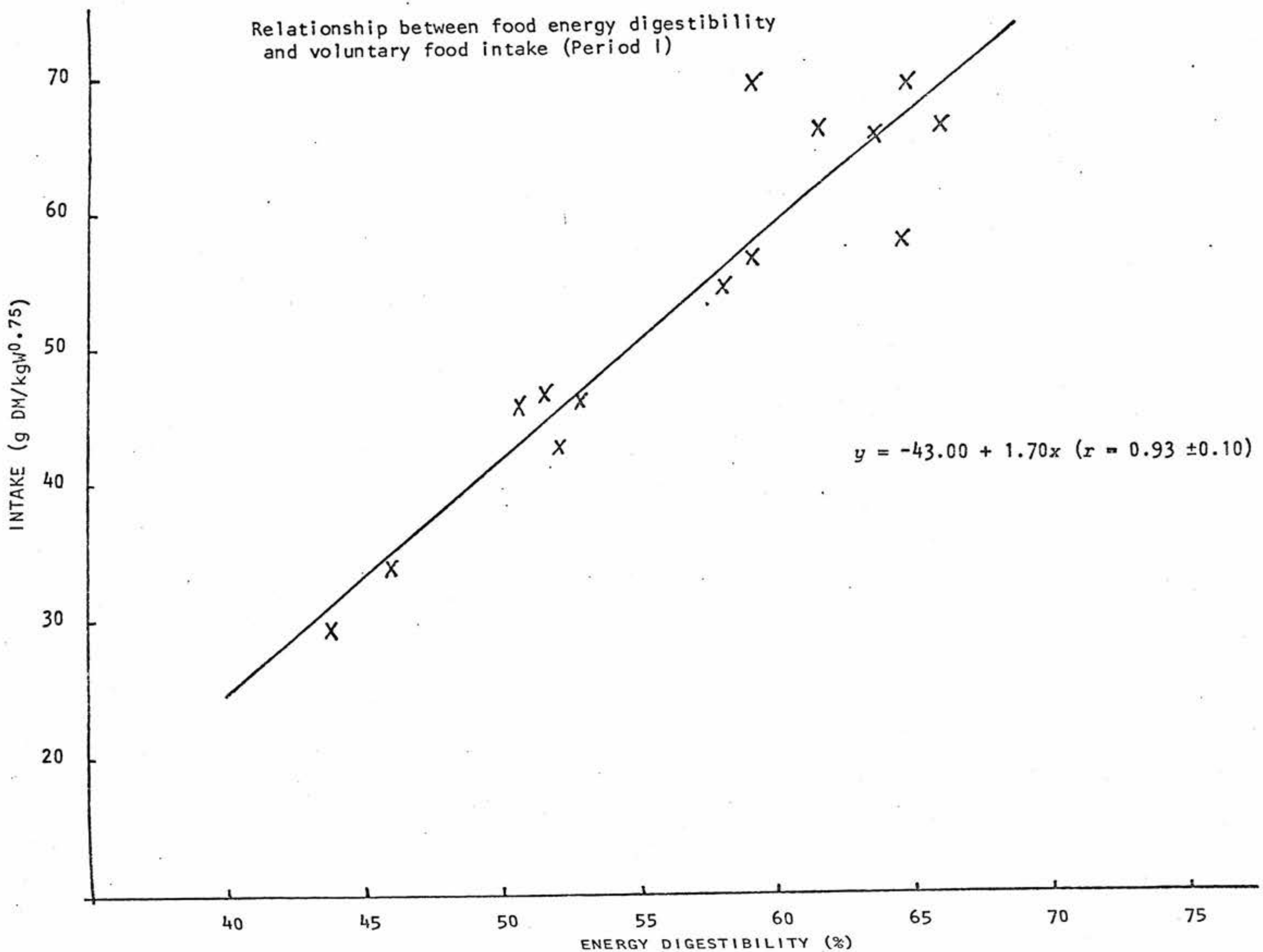


Figure 2.10

Relationship between food energy digestibility and voluntary food intake (Period II)

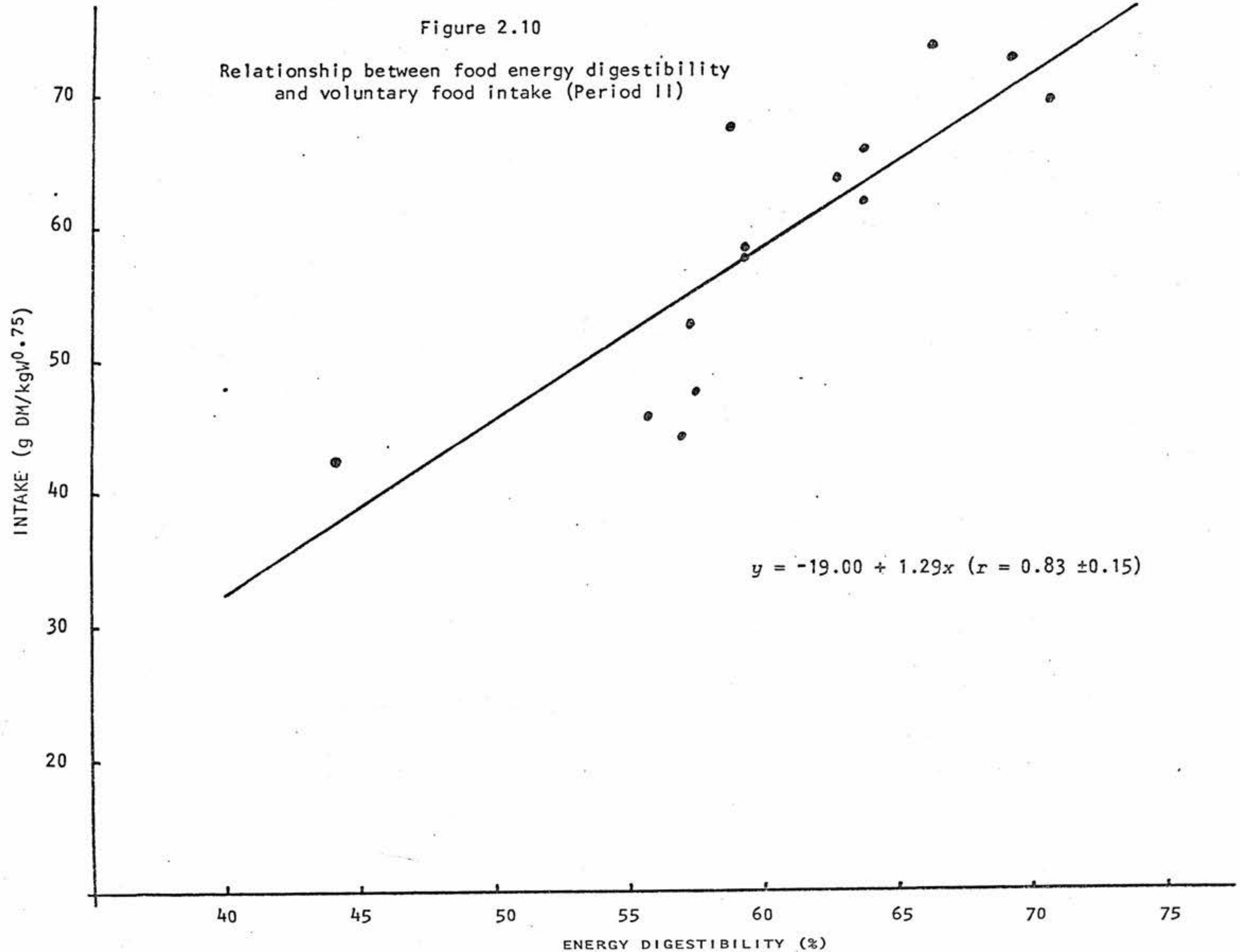
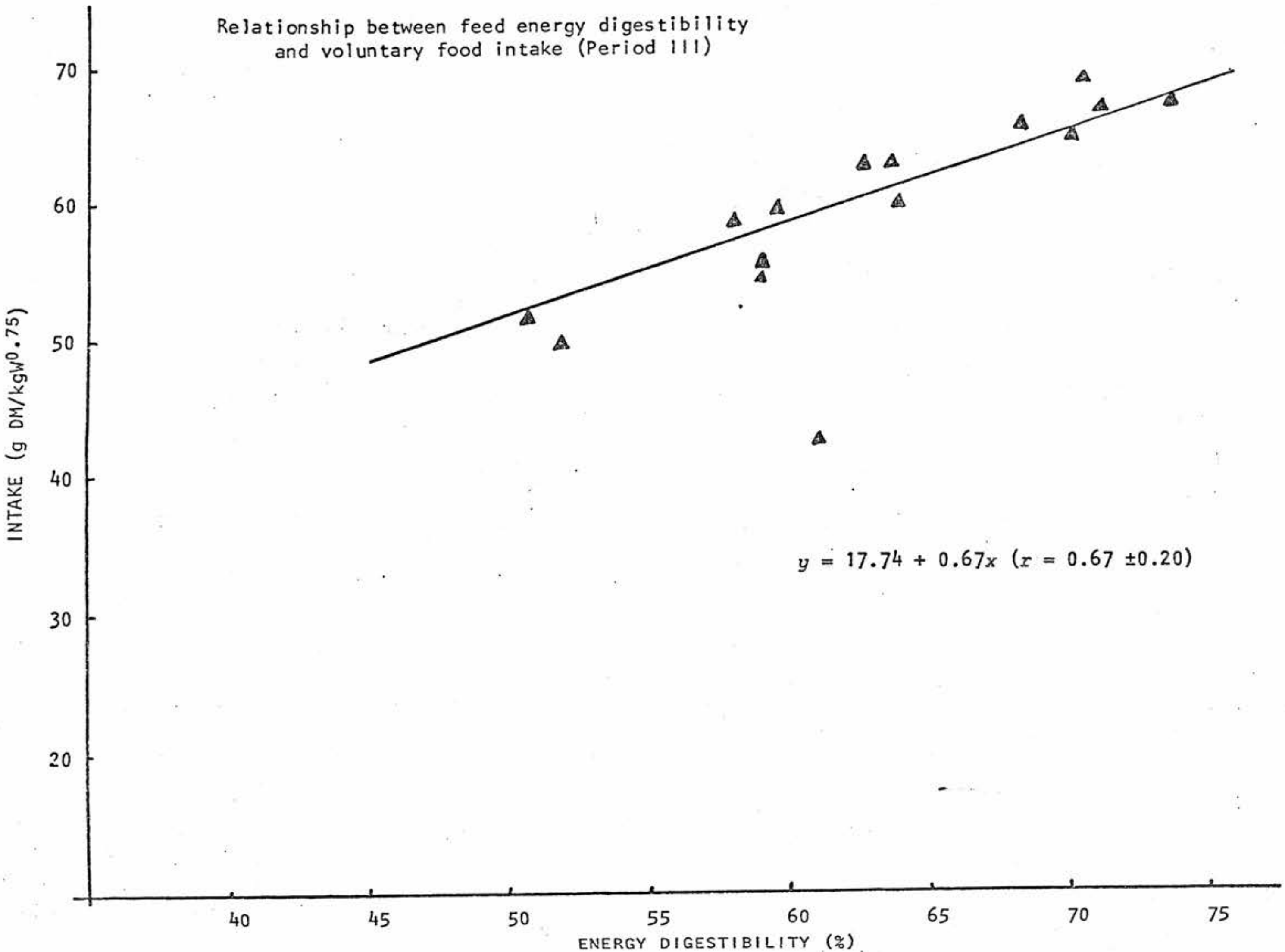


Figure 2.11

Relationship between feed energy digestibility and voluntary food intake (Period III)



Period I $y = -43.00 + 1.70x$ $(r = 0.93 \pm 0.10)$

Period II $y = -19.00 + 1.29x$ $(r = 0.83 \pm 0.15)$

Period III $y = 17.74 + 0.67x$ $(r = 0.67 \pm 0.20)$

where $y$ = intake of g DM per kg$W^{0.75}$
and $x$ = energy digestibility (%)

Figures 2.9, 2.10 and 2.11 illustrate the above relationships. Each point on the graphs represents the mean of either three or four determinations of dietary energy digestibility and four to six measurements of daily dry matter intake. As pregnancy advanced from period I to period III the relationship between energy digestibility and intake became less precise, probably due to the confounding effect of foetal number and litter weight (see below) upon intake. A similar effect was noted in Experiments 1.1, 1.2 and 1.3.

Intake per kilogram bodyweight$^{0.75}$ was calculated on a basis of bodyweight at housing. The strict accuracy of the figures derived from this basis (in Table 2.1) is open to question for period III, for on all diets, with few exceptions, the mean weight change of ewes was negative during the feeding period (see Table 3.6 opposite page 73). Since nutrient requirement is much greater as pregnancy advances (see page 57) most of the weight loss will occur towards the end of pregnancy when body reserves are most rapidly being depleted.

The equivalent calculation of intake per unit of bodyweight$^{0.75}$, using ewe weight at 24 hours post parturition, was carried out for period III. By so doing intake of dry matter per unit of bodyweight$^{0.75}$ was altered, with those ewes losing most weight appearing to have a greater intake in period III (see Table 2.1). On this basis, mean intake per kilogram of bodyweight$^{0.75}$ of all forages, except hay 4) and CRD, increased from the start of the feeding period to lambing.

The use of a cubed concentrate with a long forage may to some extent have confounded the relationship between feed digestibility and voluntary intake, particularly with hay 4). Dry matter digestibility of hay 4) was 67%, and the point at which cubed feed intake no longer has a strong positive relationship with digestibility approximates to this figure (see page 11 ), and the proportion of five parts of hay to four parts of cubed concentrate could have affected the relationship.

Adjusting the intake data by covariance made it possible to determine the effect of ewe fatness at housing upon intake. The data indicated that the fatter the ewe the less was the intake, but this effect was not significant in Experiments 2.1 and 2.2 In Experiment 2.3, however, the effect of fatness at housing achieved significance ($P<0.01$) in period I, when one unit increase in body score (Russel *et al* 1969) resulted in a reduction of 4.4 g dry matter per kilogram body-weight$^{0.75}$. In period II of Experiment 2.3 the effect of fatness upon intake just failed to achieve significance at $P<0.05$.

The above effect of ewe fatness upon intake may explain some of the discrepancy observed between total dry matter intake of food on Experiments 2.1 and 2.3 (see Table 2.1). It was observed that intakes of hays 1) and 2) were in excess of intakes of hays 5) and 7) when it would be expected that intake of hay 5) would be greater than that of hay 1) and intake of hay 7) greater than that of hay 2). Mean body scores of ewes on experiment in 1972 and 1974 were 2.9 and 3.2 respectively. The effect of fatness upon intake is in agreement with the observations of Everitt (1966), Forbes (1968, 1969a, 1970a) and Foot and Greenhalgh (1969, 1970). More of the discrepancy may be explained by the fact that hays 5) and 7) had lower nitrogen contents at higher estimated metabolizable energy values than hays 1) and 2), for intake of poor quality forages is governed by their nitrogen content (Elliot and Topps (1963).

Foetal number and weight at parturition had, with one exception, small, but non-significant effects upon the total dry matter ingested, and is in agreement with the observations of Forbes (1968, 1969a, 1970a) and Sheehan and Lawlor (1972). Data obtained from ewes fed on complete ruminant diet and hays 3) and 4) plus 30 kg of concentrate, and hay 4) plus 20 kg of concentrate, when energy and dry matter digestibilities were above 70%, would lend support to the postulation of Forbes (1970b, 1971) that metabolic factors control late pregnancy voluntary intake of highly digestible feeds (see Table 2.1). Nutrient intake was approaching, or greater than, calculated requirement (see page 63).

With all hays examined the addition of 600 or 900 g of concentrate caused a sharp reduction in voluntary forage intake followed by a gradual recovery as the proportions of the rumen microbial population adapted to the change of diet (Eadie and Mann 1970; Giesecke 1970). Forage intake recovery was more rapid when 600 g were on offer. Ewes receiving 600 or 900 g of concentrate had had the daily allowance doubled abruptly, causing digestive upset, and in some cases mild acidosis. In practice, therefore, it is advisable to increase the concentrate level more gradually.

# SECTION III

## NUTRITION OF THE PREGNANT EWE

# Nutrition of the pregnant ewe

## 1. Review of literature

### A) Feeding and management

(i) Introduction

The possible effects of fatness and pregnancy upon voluntary roughage intake have already been considered. Feeding in early pregnancy will affect the degree of fatness of the ewe during the latter part of gestation, and as a result will influence the nutritional status of the ewe in the immediate pre-parturition period. For this reason it is necessary to consider the nutrition of the breeding ewe in the periods prior to, during and after mating, and in mid-pregnancy as well as during the final eight weeks of gestation.

(ii) Mating and early pregnancy nutrition

a) Nutrition and lamb numbers

It has been shown by many workers including Marshall (1908), Clark (1934), Wallace (1953, 1955, 1961), Allen and Lamming (1961), Coop (1962a, 1966), Coop and Hayman (1962), Tribe and Seebeck (1962), McInnes and Smith (1966), Killeen (1967) and Gunn, Doney and Russel (1969) that improvement of pre-mating nutrition of ewes may lead to an elevation of the lambing percentage. According to some reports (Tribe and Seebeck 1962; Coop 1962a; 1966; McInnes and Smith 1966; Killeen 1967) lambing percentage is positively correlated with ewe body weight at mating, and Clark (1934), Allen and Lamming (1961), Coop (1966) and Gunn *et al* (1969) specify that ewe fatness, rather than body weight, governs ovulation rate and subsequent litter size.

Russel *et al* (1969) demonstrated a correlation between body fatness, as assessed subjectively by lumbar palpation, and total body chemical fat, and subsequently the investigations of Gunn *et al* (1969) and Gunn and Doney (1971) demonstrated a positive relationship between body fatness at mating and litter size at parturition in hill sheep. There is little evidence upon the effect of lowland ewes' fatness at mating upon litter size. The evidence of Bastiman (1972a) is inconclusive, but Ferguson, Barton and Duncan (unpublished data) were unable to demonstrate a relationship between body fatness at mating and litter size in crossbred lowland ewes when more than 5,000 pregnancies were monitored.

Cumming (1972) demonstrated that inadequate nutrition during the first three weeks of pregnancy reduced the percentage of embryonic implantation, and Darroch, Nordskog and Van Horn (1950) and Gunn and Doney (1973) report a reduction in litter size with a low level of nutrition post mating, the reduction being greater in ewes in poor body condition (Gunn and Doney 1973). Gerring (1954), Forbes (1969b) and the Meat and Livestock Commission (1973) recommend that until implantation of the embryos is complete, some three to four weeks after mating, ewes should be fed above the maintenance level. Killeen (1967) and Coop and Clark (1969) found no effect of early pregnancy nutrition upon litter size, possibly because even the lowest level of nutrition employed was adequate for early pregnancy.

b) Nutrition and lamb birth weight

Studies on nutrition during the first three months of gestation and its effect upon lamb birth weights have given variable results. Early reports by Thomson and Fraser (1939), Wallace (1948a, 1948b), Darroch *et al* (1950) and Gill and Thomson (1954a, 1954b) and more recent work by Hodge (1966), Killeen (1967), Coop and Clark (1969), Hulet, Foote and Price (1969) and Monteath (1971) indicated there was no effect of early pregnancy nutrition upon lamb birth weights. On the other hand, McClymont and Lambourne (1958), Bennet, Axelsen and Chapman (1964), Taplin and Everitt (1964), Everitt (1964, 1966, 1967) and Russel and Foot (1973) have found that inadequate early pregnancy nutrition was reflected in low birth weights of lambs. Some explanation of the discrepancy in published data was provided by Everitt (1964) who noted that Merino ewes that lost 12% of body weight in the first 90 days had fewer functional placental cotyledons than those gaining 12% in body weight over the same period. Ewes losing weight in early pregnancy produced lighter lambs at parturition.

The preponderance of evidence on mating and early pregnancy nutrition indicates that ewes should be fed at above the maintenance level over the period one month before and one month after mating, thus promoting the laying down of body reserves.

(iii) Mid-pregnancy nutrition

It has been observed that fatter ewes have a greater pre-disposition to pregnancy toxaemia than their thinner counterparts (Parry 1956; Reid and Hinks 1962a). Parry (1956) has demonstrated that the practice of reducing fat reserves of over-fat ewes during mid-pregnancy is beneficial, and much reduces the incidence of pregnancy toxaemia. The Meat and Livestock Commission (1973) recommend that fat ewes (condition score of 4 {Russel *et al* 1969}) should lose 5% of body weight during mid-pregnancy.

(iv) Late pregnancy nutrition

a) Effect on lamb birth weight and development

Approximately 70% of foetal growth takes place during the final six weeks of gestation (Winters and Feuffel 1936; Wallace 1948c; Wheeler, Reardon, Hedges and Rocks 1971; Lodge and Heaney 1973). Hammond (1932) noted that the size and strength of the lamb at birth could be considerably affected by the state of nutrition of the ewe during the second half of pregnancy. In the work of Thomson and Fraser (1939) ewes fed liberally throughout pregnancy (gaining 23 kg) and those fed liberally during the final month of gestation only (gaining 9 kg) had larger, stronger lambs than those being poorly fed throughout. Ewes gaining 23 kg and 0.5 kg during late pregnancy gave single lambs of similar birth weight, but ewes gaining 23 kg produced twin lambs which were 47% heavier than those produced by ewes gaining 0.5 kg (Pálsson and Vergés 1952). Wallace (1948a) found that well fed ewes produced twin lambs weighing 5.5 kg, while poorly fed ewes produced twin lambs weighing 3.4 kg.

The level of nutrition in the final two months of pregnancy has a marked effect upon both foetal and udder development (Wallace 1948a, 1948b, 1948c; Thomson and Thomson 1949; Barnicoat, Logan and Grant 1949a, 1949b; Guyer and Dyer 1954). According to Hammond (1952) and Pálsson and Vergés (1951) lighter, underdeveloped lambs are physiologically younger than larger fully developed lambs, despite similarity of chronological age. The timing and development of the various organs in the foetus was observed to be related to their functional necessity at birth (Wallace 1948a). In early pregnancy ewe weight increase was due mainly to the growth of the gravid uterus, while later the growth of foetal tissue contributed most to the weight increase, and was greater at any time for ewes carrying twins compared with singles (Wallace 1948a, 1948c). Thomson and Thomson (1949) noted that ewes drew greatly upon body reserves, when undernourished in late pregnancy, to produce their lambs. Ewes losing 5% of body weight from mid-pregnancy to immediately prior to parturition produced smaller and lower vitality singleton and twin lambs (Thomson and Thomson 1949).

Thomson (1952), summarising mainly British research work carried out on twin-bearing ewes, concluded that strong, heavy lambs can be produced by feeding their dams well throughout pregnancy, or by feeding well during the last six weeks of pregnancy only. Weak under-sized lambs are produced by ewes that are underfed throughout pregnancy, or underfed during the last six weeks of pregnancy, even when well fed earlier, or subjected to a severe nutritional check near to lambing. The timing of feeding, rather than the total amount of feed, is important, according to Thomson.

There are, however, reports of small weakly lambs being produced by ewes on a high plane of nutrition in late pregnancy (Jeffries and Fearn 1956; Reid and Hinks 1962a; Everitt 1966). Unplublished observations on pregnant Finnish Landrace x Dorset Horn ewes at the University of Edinburgh have shown that when ewes are fat (body score of 4 plus) in late pregnancy light, weakly lambs are produced. Similar observations have been made by Robinson (personal communication). The three papers cited state that the ewes on experiment were fat in late pregnancy.

(b) Effect on mortality, growth rates and ewe weight

Field studies on late pregnancy ewe nutrition are widely reported, but the results are variable. Underwood and Shier (1942) found that the feeding of 0.25 kg of wheat per day during the final six weeks of gestation had no effect upon birth weights or lamb growth, but reduced mortality at parturition. Subsequent investigations (Underwood, Shier and Carris 1943) showed that similar levels of supplementation reduced mortality and improved both lamb birth weights and liveweight gains of single and twin lambs. Darroch *et al* (1950) did not find any response to improved nutrition in late pregnancy, and Coop (1950) found that despite an increase in birth weight by ensuring a high level of nutrition in late pregnancy (ewes gaining 10 to 18 kg) there was no improvement in lamb mortality over ewes on a low plane of nutrition (ewes losing or gaining 2 kg). This variability of response may be largely explained by differences in litter size and the availability of natural forage or conserved forage during the late pregnancy period.

Thomson and Fraser (1939), Wallace (1948a), Thomson and Thomson (1949, 1953) and Pálsson and Vergés (1952) noted that low lamb birth weight increased lamb mortality.

The investigations of Wallace (1948a, 1948b, 1948c), Thomson and Thomson (1949, 1953) and Pálsson and Vergés (1952) have demonstrated the effect of extremes of nutrition upon sheep production. The data of Barnicoat *et al* (1949a, 1949b), Coop (1950), Guyer and Dyer (1954) and Gill and Thomson (1954b) indicate that where ewes were gaining very little weight in comparison with ewes gaining up to 11 kg in late pregnancy, differences in birth weights and subsequent production are not so great at those observed by Wallace (1948a, 1948b, 1948c), Thomson and Thomson (1949, 1953) and Pálsson and Vergés (1952). The differences are further reduced in the data of Coop (1950), Guyer and Dyer (1954) and Papadopoulos and Robinson (1957) when ewes gaining approximately 5 kg in late pregnancy were compared with those gaining approximately 10 kg over the same period. It would appear, therefore, that a moderate level of feeding resulting in some small mobilisation of body reserves during pregnancy is not detrimental to lamb production.

(v) Summary and conclusions

For optimum lamb production, ewes should be fed at above maintenance during the two month period prior to, during, and after mating. Once implantation is achieved the level of nutrition is less critical. The data of Parry (1956) demonstrated that deliberate nutritional restriction of fat ewes in mid-pregnancy reduces the incidence of pregnancy toxaemia, and that it is advisable to permit the loss of condition of fat ewes during the two months of mid-pregnancy. During the final third of pregnancy an increase in the plane of nutrition is necessary to support the rapid growth of the foetus. Some loss of ewe body tissue mobilised to support foetal growth is permissable, and Thomson and Aitken (1959) recommend a weight gain of 3 to 6 kg during the final six or eight weeks of pregnancy. (Further reviews of data on late pregnancy feeding and its effect upon ewe weight changes, lamb birth weights, survival and subsequent growth rates are provided by Thomson and Aitken {1959} and Schinckel {1963} ).

(vi) Late pregnancy nutrition and milk yield

The feeding and management necessary to produce viable lambs without drawing excessively upon body reserves have been discussed. It is therefore necessary to consider the effect of nutritional level in late pregnancy upon the onset of lactation and subsequent milk yield.

Wallace (1948a) and Guyer and Dyer (1954) demonstrated that under-nutrition in late pregnancy reduces udder size, and Thomson and Thomson (1953) showed that very low levels of nutrition delayed or prevented the onset of lactation. Late pregnancy nutrition most affects early lactation yield (Wallace 1948b; Thomson and Thomson 1953; Guyer and Dyer 1954; Peart 1967a; Treacher 1970) and many workers have reported that ewes poorly fed in late pregnancy have lower total milk yields than better fed ewes (Thomson and Fraser 1939; Underwood, Shier and Cariss 1943; Wallace 1948b; Barnicoat *et al* 1949b; Thomson and Thomson 1949; 1953; Guyer and Dyer 1954; Barnicoat, Murray, Roberts and Wilson 1957a; Treacher 1966, 1970; Butterworth and Blore 1969)

Hammond (1932) and Peart (1970) have found that fatter ewes produced more milk than their thinner counterparts, especially when nutrition during lactation is less than optimal (Peart 1970), and Barnicoat *et al* (1949a) believe that high levels of nutrition pre-lambing help maintain milk yields during late lactation.

There are many reports in which late pregnancy nutrition did not affect milk yield (Underwood and Shier 1942; Coop 1950; Guyer and Dyer 1954; Papadopoulos and Robinson 1957; Large, Alder and Spedding 1959; Treacher 1971). The discrepancy may be largely explained by the fact that the levels of nutrition employed in such investigations had no effect upon lamb birth weights or the onset of lactation. It has also been extensively demonstrated that milk yield is most dependent upon current nutrition and not late pregnancy nutrition (Barnicoat *et al* 1949a; Coop 1950; Barnicoat *et al* 1957a; Papadopoulos and Robinson 1957; Munro 1962; Peart 1967a, 1967b, 1968a, 1970; Treacher and Crabtree 1973) and the number of lambs suckled (Wallace 1948b; Barnicoat *et al* 1949a; 1949b; Barnicoat *et al* 1957b; Alexander, Lloyd and Davies 1959; Peart 1970, 1971).

Under-nutrition in late pregnancy may also affect the chemical composition of the colostrum (Perrin 1958) and the subsequent milk (Perrin 1958; Whiting, Slen and Bezeau 1958; Treacher 1970, 1971). More fat and protein are produced in the milk of well fed ewes. Broster (1971) states that with dairy cows, only when late pregnancy nutrition is very poor is milk composition affected.

It may be concluded that poor late pregnancy nutrition could reduce milk yield, but may wholly or partially be compensated for by heavier feeding in early lactation. Moderate planes of nutrition in late pregnancy allow similar milk yields to those obtained from ewes fed heavily in late pregnancy, and the milk will be of the same chemical composition.

In addition to the published data upon late pregnancy nutrition and ewe milk yield, shepherds hold to traditional theories. For example several shepherds interviewed in the area of The East of Scotland College of Agriculture maintain that a barley-based concentrate when offered to ewes in late pregnancy does not generate such a flush of milk at lambing as a concentrate based upon oats. Others held that swedes and/or turnips fed during late pregnancy were superior to all other forms of feeding for ensuring adequate milk supply. Dried grass in long or cubed form found support, but silage was frowned upon. All, however, stressed that when hay is fed to sheep in late pregnancy it must be of the best possible quality. Such traditional concepts require investigation to determine their validity.

B) Nutrient requirements

(i) Introduction

The above review of feeding trials indicates that ewe feed requirements rise as pregnancy advances, and that the pregnant ewe is capable of making good with body reserves some of the nutritional deficiencies that may occur. The feeding trials cited above do not quantify the energy and protein requirements of the ewe at the various stages of pregnancy.

(ii) Energy requirements

It is considered that feed requirements during early pregnancy are similar to those of the non-pregnant ewe (National Research Council 1957, 1964, 1968; Coop and Clark 1969; Robinson personal communication). The Agricultural Research Council (1965) Nutrient Requirements for Ruminants list maintenance, fattening and lactation requirements for sheep, but state that the pregnancy requirements for energy are "not available". The energy requirement for a non-pregnant 70 to 80 kg ewe is approximately 8.3 MJ per day (Agricultural Research Council 1965), the exact figure being dependent upon individual ewe weight and the energy concentration of the feed offered. Late pregnancy energy requirements of ewes are suggested by the National Research Council (1957, 1964, 1968). From the National Research Council (1968) figures, it can be calculated that the energy requirements of a 73 kg ewe during the last six weeks of gestation is 17.1 MJ of metabolisable energy per day. "Ewes producing single lambs appear to be able to subsist on slightly less, but twin-producing ewes need the level indicated or slightly more." (National Research Council 1968).

There are several methods of determining late pregnancy nutrient requirements for ewes of given weight and foetal load. Ewes of similar weight and foetal load may be offered a range of feeding levels, and from ewe weights, both during and after pregnancy the level of feeding which produces nil weight change from mating to 24 hours post-partum is considered to supply nutrient requirements (e.g. Wallace 1948c; McClelland and Forbes 1969). However, the work of Wallace (1948a, 1948b, 1948c) has indicated an increase in plasma volume, and mammary tissue weight (Wallace 1948b, 1948c; Guyer and Dyer 1954; Rattray, Garret, East and Hinman 1974) - changes which confound the issue.

To obtain estimates of nutrient requirement Langlands and Sutherland (1968) and Rattray *et al* (1974) offered pregnant ewes different levels of feeding at various stages of pregnancy and serially slaughtered ewes during gestation. The energy increment of the various maternal and foetal tissues may then be calculated, and reference to the quantity of energy ingested over the period of feeding permit further estimates of food conversion to maternal and foetal tissue in addition to those obtained from metabolism studies (e.g. Graham 1964; Modyanov 1967).

Kronfeld (1957), Reid and Hogan (1959), Reid (1960a, 1962, 1963), Reid and Hinks (1962a, 1962b, 1962c), Russel (1967, 1968), Davies and Johnston (1971), Davies, Johnston and Ross (1971), Sykes and Field (1972) and Davies and Ross (1973) have explored a third method of determining energy requirements of the pregnant ewe. The levels of glucose, free fatty acid (FFA) and ketone bodies in the blood plasma fluctuate with varying nutritional pressure (Annison 1960; Russel 1967). By monitoring these parameters and adjusting the feeding to maintain constant levels of the parameters during pregnancy it was possible to calculate the nutrient required to ensure that FFA levels were kept constant throughout pregnancy (Russel, Doney and Reid 1967a, 1967b; Robinson, Fraser and

Table 3.1

Estimated daily nutrient requirements of pregnant ewes (70-80 kg)

| Source | No. of lambs | Energy (MJ/day) | Period of gestation |
|---|---|---|---|
| Meat and Livestock Commission (1973) | 1 | 13.6 | 6-3 weeks *pre-partum* |
| | 2 | 14.6 | " " |
| | 1 | 15.0 | final 2 weeks |
| | 2 | 17.6 | " |
| National Research Council (1968) | 1 or 2 | 17.1 | final 6 weeks |
| Robinson *et al* (1971) | 2 | 15.3 | 55 days *pre-partum* |
| | | 15.5 | 45 " " |
| | | 16.2 | 35 " " |
| | | 17.1 | 25 " " |
| | | 18.5 | 15 " " |
| | | 22.2 | 5 " " |
| Spedding (1970) | 1 | 12.3* | late pregnancy |
| | 2 | 15.6* | " |
| | 3 | 17.3* | " |
| Russel *et al* (1967b) | 1 | 16.3 | late pregnancy |
| | 2 | 24.0 | " |
| Rattray *et al* (1974) | 1 | 13.3 | ∿ day 100 |
| {assuming ewe weight = 75 kg} | 2 | 14.2 | " |
| | 3 | 16.3 | " |
| | 1 | 15.7 | ∿ day 120 |
| | 2 | 18.8 | " |
| | 3 | 20.9 | " |
| | 1 | 18.7 | ∿ day 140 |
| | 2 | 23.4 | " |
| | 3 | 26.7 | " |
| Langlands and Sutherland (1968) | 1 | 9.4 | ∿ day 110 |
| | 1 | 10.3 | ∿ day 125 |
| | 1 | 11.7 | ∿ day 145 |

*assuming 8.3 MJ per day maintenance (ARC 1965)

Bennet 1971). Such estimates are higher than those obtained using slaughter or weighing techniques. The investigations of Robinson *et al* (1971) showed estimates of energy requirements to be about 180% of those obtained by Langlands and Sutherland (1968), but similar to those obtained by Rattray *et al* (1974).

Lodge (1972) speculates as to whether the rising of FFA and ketone levels is a result of nutritional stress or a direct result of pregnancy. Recent work by Leat (1974) has shown variation due to the time of year in glucose and FFA concentrations in blood plasma. Robinson (personal communication) maintains that energy requirements based upon a constancy of FFA in blood plasma greatly over-estimate late pregnancy energy requirement. Table 3.1 summarises some recent estimates of the energy requirement for ewes in the final stages of pregnancy. (Bowden {1971} has reviewed the role of FFA and ketone levels as indicators of ruminant nutritional status.)

(iii) Protein requirements

Few nutritional experiments differentiate between the levels of protein and energy in the diet. The experiments of Whitehair, Nash and Gallop (1950), Slen and Whiting (1952a, 1952b) and McClelland and Forbes (1968) have demonstrated that a deficiency of protein may reduce lamb birth weights and subsequent milk yield (Robinson and Forbes 1968) and lamb growth rate (Slen and Whiting 1952a, 1952b). Whitehair *et al* (1950) report a higher proportion of still births and neonatal mortality with protein deficiency, and Robinson, Fraser, Corse and Gill (1970) report that ewes on a constant or increasing level of protein produced heavier lambs than those on a decreasing level of protein. In an experiment designed to test the effect of protein level in late pregnancy upon ewe performance and lamb birth weight McClelland and Forbes (1971) found that despite very low levels of protein no significant differences were apparent.

Table 3.2

Protein requirements (g per day)
for a 70-80 kg ewe during pregnancy

| Source | No. of lambs | protein (g) | Period of gestation |
|---|---|---|---|
| National Research Council (1968) | 1 or 2 | 168 CP* | final 6 weeks |
| Meat and Livestock Commission (1973) | 1 | 225 CP | final 2 weeks |
| | 2 | 250 CP | " |
| ARC (1965) | 1 | 33 AP** | 3rd month |
| | 2 | 39 AP | " |
| | 1 | 44 AP | 4th month |
| | 2 | 60 AP | " |
| | 1 | 80 AP | 5th month |
| | 2 | 100 AP | " |
| Lodge (1972) | 2 | 27 AP | 0 days |
| {60 kg ewe} | 2 | 30 AP | 50 " |
| | 2 | 40 AP | 90 " |
| | 2 | 50 AP | 110 " |
| | 2 | 60 AP | 125 " |
| | 2 | 70 AP | 135 " |
| | 2 | 80 AP | 145 " |

*crude protein

**available protein

There are many references to the quantity of protein to be offered to pregnant ewes (see Lodge 1972), but the requirement will depend upon the weight of the ewe, the foetal load and the feed on offer. The data of Whiting and Slen (1958), Robinson and Forbes (1967, 1968) and Robinson *et al* (1970) indicated that the proportion of protein to energy was important in determining the quantity of protein required by the ewe in late pregnancy. Slen and Whiting (1952a) offered to pregnant ewes diets containing 7, 10 or 13% protein and found that ewes receiving 10 or 13% protein produced heavier lambs than those receiving a diet containing 7% protein. Subsequent studies (Slen and Whiting 1952b) demonstrated that an increase in protein level in mid-pregnancy from 7.7% protein to approximately 10.5% gave similar results to those ewes fed at a constant 10% protein throughout pregnancy. Robinson (personal communication) suggests that 12% crude protein in the total diet is optimal, and 8% may be tolerated. However, a level of 10% should suffice under practical conditions. Nitrogen retention is increased after the 90th day of gestation (Robinson and Forbes 1967; Robinson *et al* 1970), and Robinson *et al* (1970) emphasize the ability of the ewe to draw upon body reserves. Table 3.2 indicates late pregnancy protein requirements calculated from recent sources.

(iv) Summary and conclusions

The nutritional requirements of the pregnant ewe at a given stage of gestation will vary with the foetal load, maternal weight and body condition. According to the National Research Council (1968) "lack of energy is probably the most common manifestation of nutritional deficiency in sheep", and the literature indicates that the level of protein in the diet necessary to meet requirement is not yet agreed, but the ewe has a large capacity for buffering protein deprivation.

Where foetal load is known the ewe may be fed accordingly, but on-the-farm techniques of diagnosing foetal numbers are not yet generally available (Wilson and Newton 1969). It is therefore necessary to feed to the anticipated flock mean litter size, with the inherent inaccuracy of over-feeding ewes carrying singles and under-feeding ewes with multiple foetal loads.

In the subsequent calculations and discussions of energy levels presented below the energy requirement of the 70 to 80 kg ewe carrying twin lambs is considered to approximate to the mean of the presented published estimates of late pregnancy energy requirements. In practice the figures derived approximate to the energy requirement of the non-pregnant ewe suggested by the Agricultural Research Council (1965) plus the energy required by the foetuses determined by Rattray *et al* (1974).

## 2. Late pregnancy nutrition of the ewe

### Experimental report

### Introduction

A search of the literature reveals a dearth of information upon the effect of hay quality upon nutrient consumed by ewes in late pregnancy. Of the many late pregnancy feeding trials cited above only those of Wallace (1948a) and Guyer and Dyer (1954) make reference to the effect of hay quality upon ewe and lamb performance. The individual feeding trials reported in Sections I and II of this dissertation were designed to provide information on hay and concentrate intake and thus supply the basic information for the calculation of nutrient consumption. Nutrient intakes of ewes on hay alone diets are presented prior to considering the effect of the level of concentrate upon nutrient ingested.

The literature permits the conclusion that moderate under-nourishment leading to a small depletion of ewe body reserves in late pregnancy is acceptable. Despite the many references to nutrient requirement of the ewe in late pregnancy there does not appear to be published data upon that nutrient necessary for adequate performance. In addition to providing intake data individually penned ewes were blood sampled regularly to provide biochemical data upon the state of body reserves depletion occurring on each diet as pregnancy advanced.

The number of individually fed ewes on each treatment was insufficient to provide accurate assessment of the effects of the nutrient intakes achieved upon ewe and lamb performance. To obtain an estimate of the effect of concentrate level upon ewe and lamb performance when *ad libitum* hay diets were on offer groups of approximately 25 ewes were offered one of four of the hays on test plus one of the four levels of concentrate.

Table 3.3

Mean energy (MJ) and crude protein (g CP) of ewes on intake trials in late pregnancy

| | Day 49-40 pre-parturition | | Day 31-22 pre-parturition | | Day 14-5 pre-parturition | |
|---|---|---|---|---|---|---|
| Hay | energy | protein | energy | protein | energy | protein |
| 1) | 4.7 | 52.4 | 6.8 | 83.0 | 6.7 | 81.7 |
| 2) | 8.2 | 90.3 | 8.7 | 95.0 | 9.8 | 107.1 |
| 3) | 13.1 | 128.1 | 13.6 | 132.4 | 12.6 | 110.9 |
| 4) | 16.8 | 241.2 | 16.9 | 242.7 | 16.2 | 220.5 |
| 5) | 7.3 | 73.0 | 6.5 | 73.7 | 6.7 | 77.5 |
| 6) | 6.8 | 70.3 | 7.7 | 79.8 | 6.7 | 66.4 |
| 7) | 8.5 | 79.2 | 8.8 | 82.1 | 7.7 | 69.6 |
| 8) | 9.7 | 94.3 | 9.5 | 92.7 | 8.8 | 93.5 |
| CRD 1973 | 27.9 | 350.3 | 25.5 | 320.8 | 26.2 | 332.0 |
| CRD 1974 | 28.6 | 359.0 | 26.0 | 326.2 | 23.3 | 293.1 |
| Requirement | 11.6* | 200.0** | 15.3* | 225.0+** | 19.8* | 250.0** |

*ARC (1965) plus Rattray *et al* (1974)

**Meat and Livestock Commission (1973)

+mean of 200 and 250 g CP

A) Ability of hay to satisfy nutrient requirements

(i) Materials and methods

The intake data from trials 1.1, 1.2 and 1.3 and the analysed nutrient content of the hays were used to calculate the energy and protein consumption by ewes offered hay alone during the final eight weeks of gestation.

(ii) Energy

Table 3.3 shows the mean daily energy intakes achieved by ewes at three stages during the late pregnancy feeding period when hays alone were offered. It is evident that at the stages of pregnancy considered none of the hays tested, with the exceptions of hays 3) and 4) satisfies energy requirement (ARC {1965} plus Rattray *et al* 1974) at approximately seven to six weeks prior to parturition. Only hay 4) supplied sufficient nutrients during the period 31 to 22 days pre-parturition. None satisfied energy requirement during the final two weeks of gestation. The energy deficit of offering hays alone varied with the forages supplied, this deficit being dependent upon forage energy concentration and voluntary food intake.

(iii) Protein

The corresponding protein intakes of ewes are summarized in Table 3.3. Hay 4) was the only forage that supplied sufficient crude protein to satisfy requirement (Meat and Livestock Commission 1973) at any stage, and did so until three weeks prior to parturition. The protein deficiency on the hay alone diets was dependent upon the protein content of the forage and the quanity of dry matter consumed.

Table 3.4

Mean energy intake of ewes on intake trials at three stages in late pregnancy (MJ per day)

| Diet | | Day 49-40 pre-parturition | | | Day 31-22 pre-parturition | | | Day 14-5 pre-parturition | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Hay | Conc | Hay | Conc | Total | Hay | Conc | Total | Hay | Conc | Total |
| 1 | 30 | 4.6 | 1.6 | 6.2 | 4.8 | 4.9 | 9.7 | 3.7 | 9.7 | 13.4 |
| | 20 | 3.8 | 1.1 | 4.9 | 4.4 | 3.2 | 7.6 | 3.6 | 6.5 | 10.1 |
| | 10 | 5.8 | 0.5 | 6.3 | 6.1 | 1.6 | 7.7 | 6.5 | 3.3 | 9.8 |
| | 0 | 4.7 | - | 4.7 | 6.8 | - | 6.8 | 6.7 | - | 6.7 |
| 2 | 30 | 7.9 | 1.6 | 9.5 | 7.9 | 4.9 | 12.8 | 5.2 | 9.7 | 14.9 |
| | 20 | 7.8 | 1.1 | 8.9 | 7.6 | 3.2 | 10.8 | 6.6 | 6.5 | 13.1 |
| | 10 | 8.5 | 0.5 | 9.0 | 8.0 | 1.6 | 9.6 | 9.3 | 3.3 | 12.6 |
| | 0 | 8.2 | - | 8.2 | 8.7 | - | 8.7 | 9.8 | - | 9.8 |
| 3 | 30 | 13.6 | 1.6 | 15.2 | 13.4 | 4.7 | 18.1 | 8.2 | 9.5 | 17.7 |
| | 20 | 12.5 | 1.1 | 13.6 | 11.8 | 3.3 | 15.1 | 9.3 | 6.3 | 15.6 |
| | 10 | 12.0 | 0.5 | 12.5 | 13.0 | 1.6 | 13.6 | 11.4 | 3.3 | 14.7 |
| | 0 | 13.1 | - | 13.1 | 13.6 | - | 13.6 | 12.6 | - | 12.6 |
| 4 | 30 | 16.9 | 1.6 | 18.5 | 14.8 | 4.7 | 19.5 | 10.2 | 9.5 | 19.7 |
| | 20 | 16.0 | 1.1 | 17.1 | 15.2 | 3.3 | 18.5 | 10.9 | 6.3 | 17.2 |
| | 10 | 16.6 | 0.5 | 17.1 | 16.0 | 1.6 | 17.6 | 14.1 | 3.3 | 17.4 |
| | 0 | 16.8 | - | 16.8 | 16.9 | - | 16.9 | 16.2 | - | 16.2 |
| 5 | 30 | 6.2 | 1.6 | 7.8 | 6.3 | 4.7 | 11.0 | 3.7 | 9.5 | 13.2 |
| | 20 | 9.7 | 1.1 | 10.8 | 6.2 | 3.3 | 9.5 | 4.6 | 6.3 | 10.9 |
| | 0 | 7.3 | - | 7.3 | 6.5 | - | 6.5 | 6.7 | - | 6.7 |
| 6 | 30 | 6.8 | 1.6 | 8.4 | 5.6 | 4.7 | 10.3 | 3.6 | 9.5 | 13.1 |
| | 20 | 8.1 | 1.1 | 9.2 | 8.6 | 3.3 | 11.9 | 5.9 | 6.3 | 12.2 |
| | 10 | 8.2 | 0.5 | 8.7 | 8.4 | 1.6 | 10.0 | 7.6 | 3.3 | 10.9 |
| | 0 | 6.8 | - | 6.8 | 7.7 | - | 7.7 | 6.7 | - | 6.7 |
| 7 | 30 | 9.0 | 1.6 | 10.6 | 8.6 | 4.7 | 13.3 | 5.2 | 9.5 | 14.7 |
| | 20 | 10.5 | 1.1 | 11.6 | 9.4 | 3.3 | 12.7 | 8.1 | 6.3 | 14.4 |
| | 10 | 10.1 | 0.5 | 10.6 | 9.8 | 1.6 | 11.4 | 6.2 | 3.3 | 9.5 |
| | 0 | 8.5 | - | 8.5 | 8.8 | - | 8.8 | 7.7 | - | 7.7 |
| 8 | 20 | 11.4 | 1.1 | 12.5 | 9.7 | 3.3 | 13.0 | 8.1 | 6.3 | 14.4 |
| | 10 | 9.5 | 0.5 | 10.0 | 11.2 | 1.6 | 12.7 | 9.7 | 3.3 | 13.0 |
| | 0 | 9.7 | - | 9.7 | 9.5 | - | 9.5 | 8.8 | - | 8.8 |
| Requirement | | | 11.6 | | | 15.3 | | | 19.8 | |

ARC (1965) plus Rattray *et al* (1974)

Table 3.5

Mean protein intake of ewes on intake trials at three stages in late pregnancy (g crude protein per day)

| Diet | | Day 49-40 pre-parturition | | | Day 31-22 pre-parturition | | | Day 14-5 pre-parturition | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Hay | Conc | Hay | Conc | Total | Hay | Conc | Total | Hay | Conc | Total |
| 1 | 30 | 56.4 | 18.5 | 74.9 | 57.9 | 55.4 | 113.3 | 44.9 | 110.9 | 155.8 |
| | 20 | 47.1 | 12.3 | 59.4 | 54.4 | 37.0 | 91.4 | 44.0 | 74.0 | 118.0 |
| | 10 | 71.2 | 6.2 | 83.4 | 74.5 | 18.5 | 93.0 | 79.8 | 37.0 | 116.8 |
| | 0 | 52.4 | - | 52.4 | 83.0 | - | 83.0 | 81.7 | - | 81.7 |
| 2 | 30 | 86.5 | 18.5 | 105.0 | 86.8 | 55.4 | 142.2 | 57.5 | 110.9 | 168.4 |
| | 20 | 85.6 | 12.3 | 97.9 | 83.4 | 37.0 | 120.4 | 72.9 | 73.9 | 146.8 |
| | 10 | 93.1 | 6.2 | 99.3 | 88.0 | 18.5 | 106.5 | 102.3 | 37.0 | 139.3 |
| | 0 | 90.3 | - | 90.3 | 95.0 | - | 95.0 | 107.1 | - | 107.1 |
| 3 | 30 | 135.0 | 18.2 | 153.2 | 130.7 | 53.2 | 183.9 | 80.8 | 107.8 | 188.6 |
| | 20 | 122.1 | 12.6 | 134.7 | 114.4 | 37.8 | 152.2 | 101.5 | 71.4 | 172.9 |
| | 10 | 117.0 | 5.6 | 122.6 | 126.4 | 18.2 | 144.6 | 111.8 | 37.8 | 149.6 |
| | 0 | 128.1 | - | 128.1 | 132.4 | - | 132.4 | 110.9 | - | 110.9 |
| 4 | 30 | 241.2 | 18.2 | 259.4 | 213.1 | 53.2 | 266.3 | 146.5 | 107.8 | 254.3 |
| | 20 | 229.4 | 12.6 | 242.0 | 219.0 | 37.8 | 256.8 | 156.9 | 71.4 | 228.3 |
| | 10 | 238.3 | 5.6 | 243.9 | 230.9 | 18.2 | 249.1 | 202.7 | 37.8 | 240.5 |
| | 0 | 241.2 | - | 241.2 | 242.7 | - | 242.7 | 220.5 | - | 220.5 |
| 5 | 30 | 70.7 | 18.2 | 88.9 | 70.7 | 53.2 | 123.9 | 42.6 | 107.8 | 150.4 |
| | 20 | 74.5 | 12.6 | 87.1 | 73.0 | 37.8 | 110.8 | 52.4 | 71.4 | 123.8 |
| | 0 | 73.0 | - | 73.0 | 73.7 | - | 73.7 | 77.5 | - | 77.5 |
| 6 | 30 | 71.1 | 18.2 | 89.3 | 58.5 | 53.2 | 111.7 | 37.9 | 107.8 | 145.7 |
| | 20 | 83.7 | 12.6 | 96.3 | 89.3 | 37.8 | 127.1 | 61.6 | 71.4 | 133.0 |
| | 10 | 85.3 | 5.6 | 90.9 | 86.1 | 18.2 | 104.3 | 62.4 | 37.8 | 100.2 |
| | 0 | 70.3 | - | 70.3 | 79.8 | - | 79.8 | 66.4 | - | 66.4 |
| 7 | 30 | 84.4 | 18.2 | 102.6 | 80.7 | 53.2 | 133.9 | 48.8 | 107.8 | 156.6 |
| | 20 | 98.4 | 12.6 | 111.0 | 88.1 | 37.8 | 125.9 | 76.2 | 71.4 | 147.6 |
| | 10 | 94.7 | 5.6 | 100.3 | 91.8 | 18.2 | 110.0 | 57.7 | 37.8 | 95.5 |
| | 0 | 79.2 | - | 79.2 | 82.1 | - | 82.1 | 69.6 | - | 69.6 |
| 8 | 20 | 111.5 | 12.6 | 124.1 | 95.1 | 37.8 | 132.9 | 78.7 | 71.4 | 150.1 |
| | 10 | 105.0 | 5.6 | 110.6 | 101.7 | 18.2 | 119.9 | 95.1 | 37.8 | 132.9 |
| | 0 | 94.3 | - | 94.3 | 92.7 | - | 92.7 | 93.5 | - | 93.5 |
| Requirement MLC (1973) | | | | 200 | | | | 250 | | |

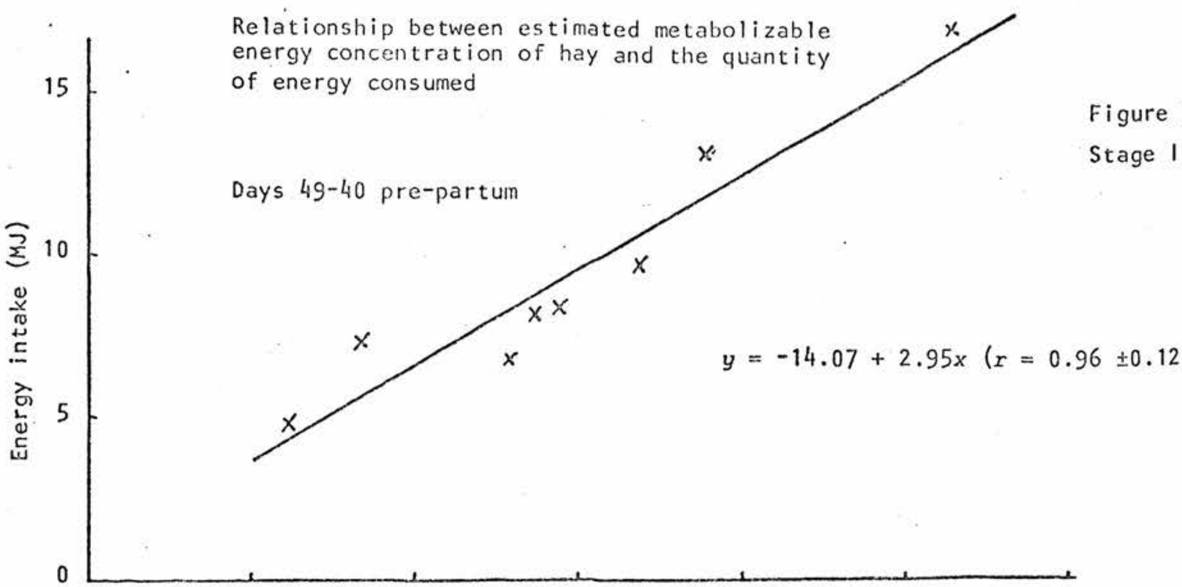



Figure 3.1
Stage I

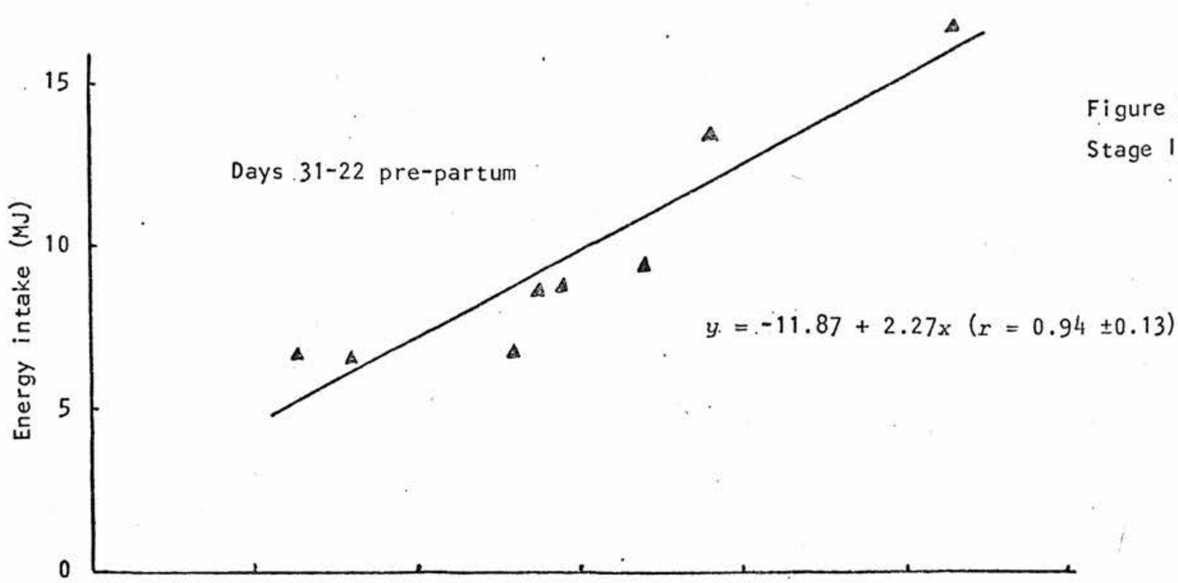



Figure 3.2
Stage II

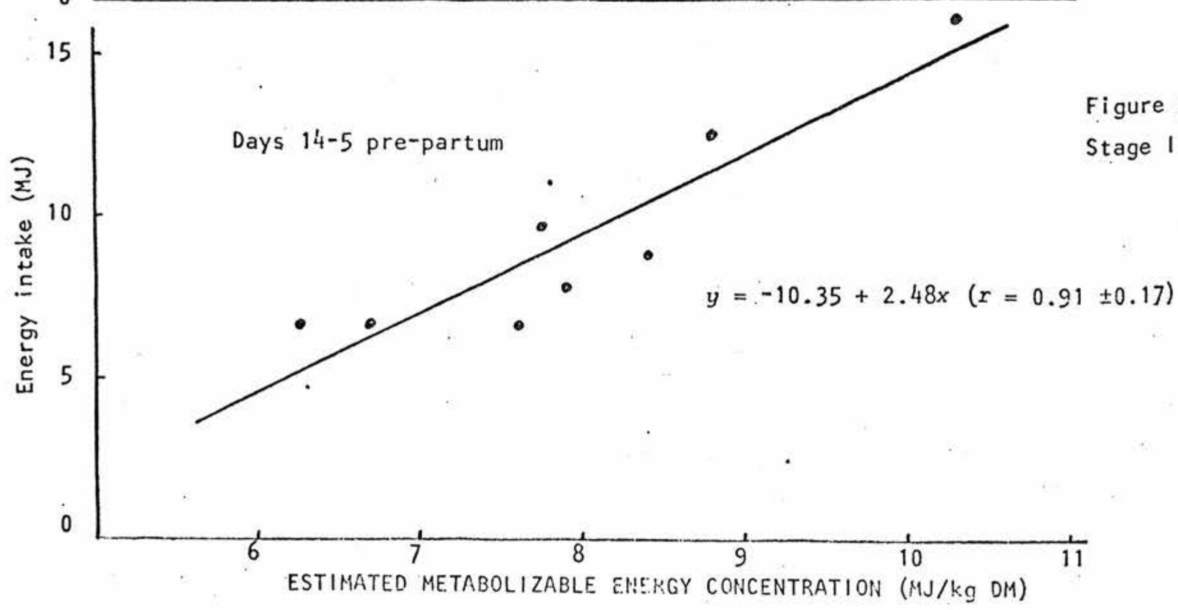
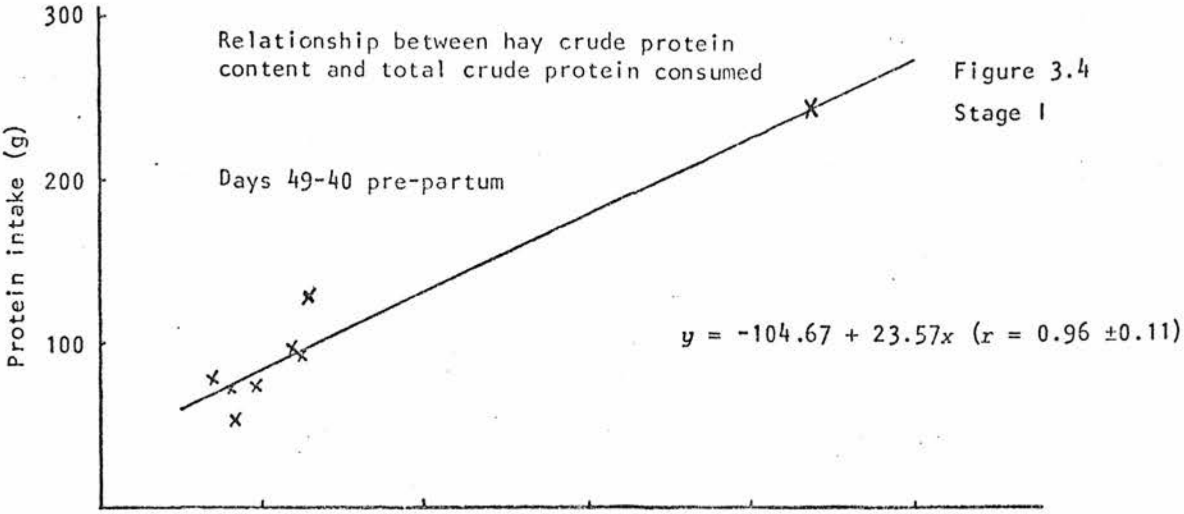
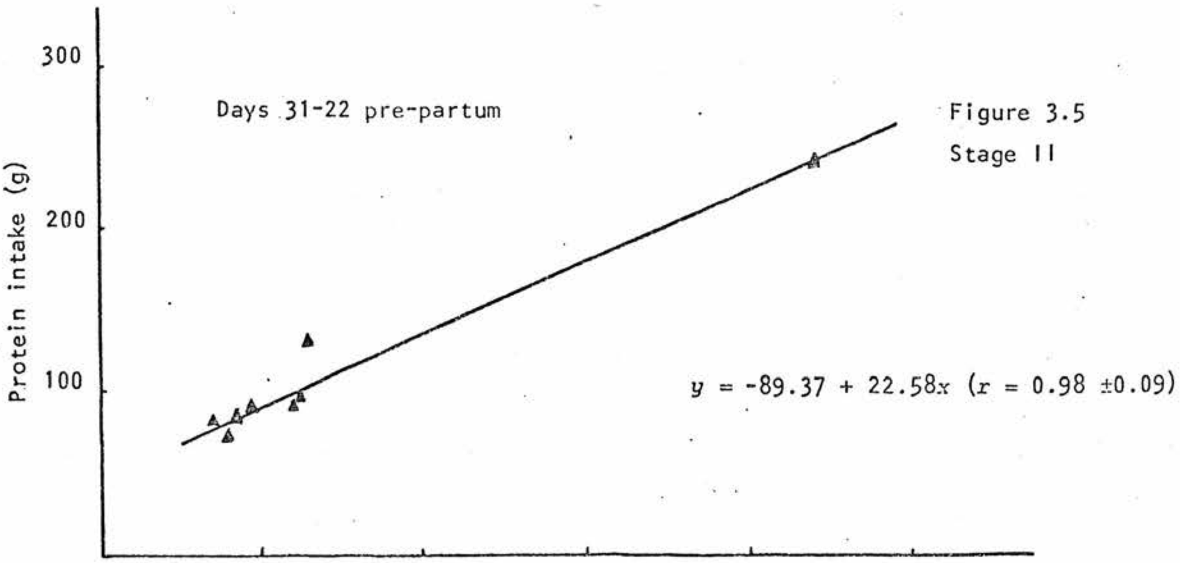



Figure 3.3
Stage III



Relationship between hay crude protein content and total crude protein consumed
Figure 3.4
Stage I
Days 49-40 pre-partum
Protein intake (g)
300
200
100
$y = -104.67 + 23.57x$ ($r = 0.96 \pm 0.11$)

Days 31-22 pre-partum
Figure 3.5
Stage II
Protein intake (g)
300
200
100
$y = -89.37 + 22.58x$ ($r = 0.98 \pm 0.09$)

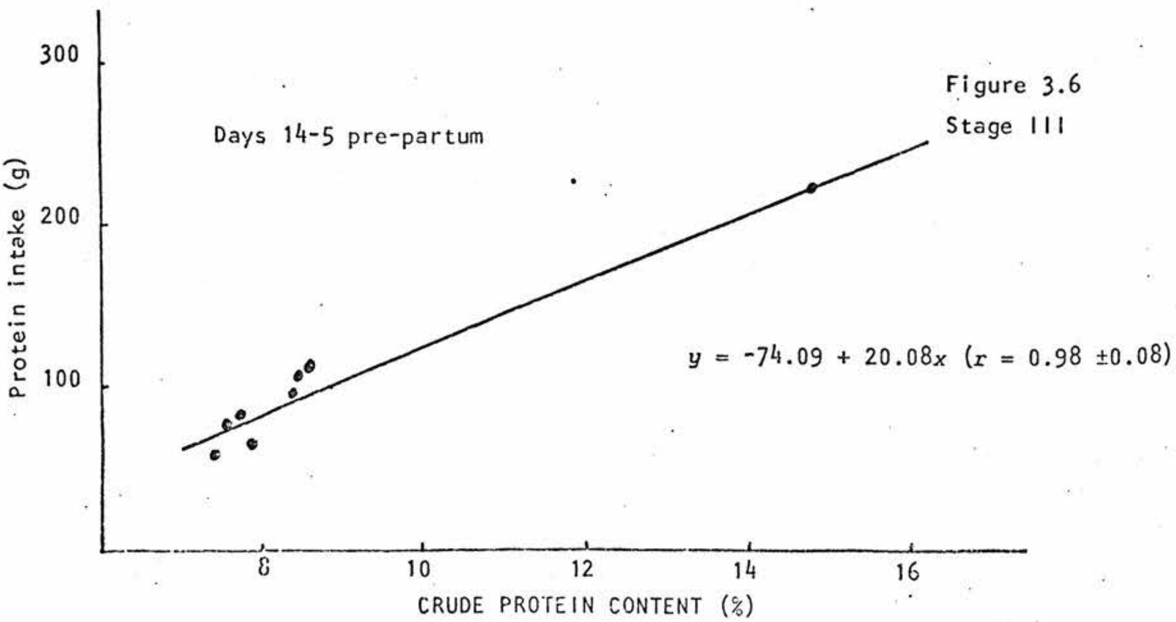



Figure 3.6
Stage III
Days 14-5 pre-partum
Protein intake (g)
300
200
100
$y = -74.09 + 20.08x$ ($r = 0.98 \pm 0.08$)
8
10
12
14
16
CRUDE PROTEIN CONTENT (%)

B) The quantity of concentrate required to raise nutrient intake to requirement

(i) Energy

During the period 49 to 40 days prior to lambing, ewes on diets containing hays other than 3) or 4), did not receive the calculated energy requirements, with the exception of ewes offered hays 7) and 8) plus a total of 20 kg of concentrate. Four to three weeks pre-lambing, energy requirement was supplied to ewes on all diets based upon hays 3) and 4) only. During the final two weeks of pregnancy only the ewes on the diet of hay 4) plus 30 kg of concentrate received the calculated energy requirements. Table 3.4 indicates the energy intake of ewes on all diets.

(ii) Protein

The amount of supplement required during the last few weeks of gestation to make good the deficiency was, with the exception of ewes on hay 4), above the largest quantity of supplement offered. Protein intakes achieved on all diets are shown in Table 3.5.

(iii) Discussion and conclusions

Hay quality (estimated metabolizable energy value, and *in vitro* organic matter digestibility) governed the intake of dry matter by the pregnant ewe (see Section I), and has governed the resultant energy and protein ingested. Figures 3.1, 3.2 and 3.3 illustrate the relationships between the estimated metabolizable energy of hay and the total energy consumed by ewes during three stages in the late pregnancy feeding period. Similarly Figures 3.4, 3.5 and 3.6 show the relationships between protein content of the forage and the total protein consumed. Using the pooled data for the three years of experimentation equations relating hay quality (estimated metabolizable energy in MJ per kg dry matter, and *in vitro* organic matter digestibility) to energy intake from hay were derived for the three stages of pregnancy considered:

| | | |
|---|---|---|
| Stage I | $y = -14.07 + 2.95x$ | ($r$ = 0.96 ±0.12) |
| Stage II | $y = -11.87 + 2.72x$ | ($r$ = 0.94 ±0.13) |
| Stage III | $y = -10.35 + 2.48x$ | ($r$ = 0.91 ±0.17) |

where $y$ = total energy ingested (MJ)
and $x$ = estimated energy content of forage (MJ/kg DM)

The relationship between *in vitro* organic matter digestibility and energy intakes at three stages of pregnancy considered were as follows:

| | | |
|---|---|---|
| Stage I | $y = -18.41 + 0.53x$ | ($r$ = 0.99 ±0.06) |
| Stage II | $y = -15.89 + 0.49x$ | ($r$ = 0.97 ±0.09) |
| Stage III | $y = -14.63 + 0.46x$ | ($r$ = 0.96 ±0.11) |

where $y$ = total energy ingested (MJ)
and $x$ = *in vitro* organic matter digestibility

The corresponding relationships between hay crude protein content and total crude protein consumed are expressed by the following equations:

| | | |
|---|---|---|
| Stage I | $y = -104.67 + 23.57x$ | ($r$ = 0.96 ±0.11) |
| Stage II | $y = -89.37 + 22.58x$ | ($r$ = 0.98 ±0.09) |
| Stage III | $y = -74.09 + 20.08x$ | ($r$ = 0.98 ±0.08) |

where $y$ = total crude protein intake (g CP)
and $x$ = crude protein content of the forage

Based upon the above equations, to satisfy energy (ARC {1965} plus Rattray *et al* 1974) and protein (Meat and Livestock Commission 1973) requirements for the 70 to 80 kg ewe carrying twin lambs at the three stages of gestation, forages of the following *in vitro* organic matter digestibility, energy and crude protein concentrations would be required if offered to appetite:

| | *In vitro* organic matter digestibility % | Crude protein % (in dry matter) | Energy concentration (MJ/kg DM) |
|---|---|---|---|
| Stage I | 56.6 | 12.9 | 8.7 |
| Stage II | 63.6 | 13.9 | 10.0 |
| Stage III | 74.8 | 16.1 | 12.2 |

The above figures suggest that when high quality forage is available, rationing may be advisable during the first stage of the feeding period {e.g. hays 3) and 4)}. It is also evident that if a series of above average forages are available the best should be kept until the later stages of pregnancy when nutrition is more critical.

If hays of poor quality are supplied to ewes in late pregnancy, very high levels of concentrate feeding are necessary to meet nutrient requirements, particularly during the final four weeks of gestation. Duncan (1973) offering *ad libitum* hay of similar quality to hay 8), to pregnant Scottish Halfbred ewes, plus a total of 29 kg of concentrate during the final six weeks of pregnancy, found that voluntary nutrient intake during the final three weeks of gestation was below 15.0 MJ of metabolizable energy per day. Both Duncan (1973) and Shevah (1974) found that *ad libitum* concentrates and 250 g hay (to prevent acidosis) did not supply sufficient energy or protein to satisfy what they calculated to be the nutrient requirement.

Literature cited above makes reference to many investigations in which nutrient intake in late pregnancy was below requirement without detriment to the lambs born, and subsequent performance (e.g. Underwood and Shier 1942; Darroch *et al* 1950; Coop 1950; Guyer and Dyer 1954; Papadopoulos and Robinson 1957). Several report the total nutrient ingested (Sheehan, Lawlor and Bath 1972; Sheehan and Lawlor 1972; Duncan 1973; Rattray *et al* 1974) defining more exactly that moderate under-nutrition may be tolerated by the ewe in late pregnancy. Sheehan and Lawlor (1972) concluded that supplementation of roughage diets need not be so great as to meet the published nutrient requirements. It therefore becomes necessary to determine the degree of under-nutrition that may be tolerated by the ewe in late pregnancy when fed on diets containing hays of different qualities. The following investigations were to provide some estimate of the level of nutrition compatible with satisfactory physical performance of both ewes and lambs.

C) Determination of the level of feeding necessary to ensure adequate physical performance

(i) Introduction

It has already been stressed that hay quality affects the intake of energy by the pregnant ewe, and that the quantity of concentrate supplement necessary to meet nutrient requirement is dependent upon the intake of a given forage. Williams, Sylvestre, Bowstead, Ewen, Myhr and Peters (1950), Coop (1951) and Stamp (1968) recommend a gradual increase in nutrient offered. Advisory publications (North of Scotland Agricultural College 1958, 1972; Ministry of Agriculture, Fisheries and Food 1964; West of Scotland College of Agriculture 1969) stress the feeding of concentrates to ewes in late pregnancy, the quantities suggested being vague, and the recommended time of commencement of feeding varying from eight weeks (Ministry of Agriculture, Fisheries and Food 1964) to five weeks (North of Scotland Agricultural College 1972) prior to projected lambing date. All, however, recommend a gradual increase in the amount of concentrate offered to 0.5 kg per day or more during the final weeks of gestation. Scant attention is paid to the quality of the basal roughage on offer.

According to Frederickson and Gordon (1958) and Reid (1958, 1963) the level of plasma FFA is a reflection of the extent of mobilization of body fat, the higher the amount of FFA the greater is the nutritional stress. Russel *et al* (1967a) considered that 750 micro-equivalents ($\mu$-equiv/l) of FFA and eight milligrams per 100 millilitres (mg%) of acetone correspond to moderate and severe under-nutrition respectively. Russel (1968) concluded that under-nutrition was best characterised by reference to a combination of FFA and ketone levels, the level of FFA reflecting the state of moderate under-nutrition more accurately than the ketone concentration. When nutritional stress is more severe the ketone level affords greater precision (Russel 1968). Both Russel (personal communication) and Skedd (personal communication) suggest that 4 mg% acetone in the peripheral plasma is characteristic of moderate, permissable inroads upon body reserves during late pregnancy. Reid (personal communication) also endorses this figure as indicative of permissable inroads upon body reserves.

The purpose of the investigations now reported was to establish

1) the quantity of supplement necessary to ensure satisfactory ewe and lamb performance, and

2) to determine the point in gestation at which supplementation with concentrates would be required with hays of different quality when offered to appetite.

Preliminary investigations (Black 1972; Duncan 1973, personal communication) indicated that with a hay of estimated metabolizable energy value of 8.5 MJ per kg dry matter supplemented with either 13.6, 22.7, 31.7 or 40.8 kg of concentrate during the final six weeks of gestation, had no effect upon ewe or lamb performance. The effect of a total of either 0, 10, 20 or 30 kg of a standard concentrate supplied over the final eight weeks of pregnancy upon ewe and lamb performance was investigated.

In Experiments 3.1, 3.2 and 3.3 the point in gestation at which concentrate feeding need commence with each hay (using the blood ketone level above 4 mg% to determine time to commence), and the quantity of feed required to prevent excessive reduction in body reserves was determined. In Experiments 3.4 and 3.5 the effect of the level of concentrate feeding in late pregnancy upon changes in ewe weight and condition, lamb birth weight and mortality, and subsequent ewe and lamb performance was monitored.

(ii) Materials and methods

a) Individual feeding trials

The necks of ewes on intake and digestibility studies (Experiments 1.1, 1.2, 1.3, 2.1, 2.2 and 2.3) were shaved at housing. Ewes were restrained and blood samples were withdrawn from the jugular vein at regular intervals throughout the feeding period by means of the "Vacutainer System" (Beckton-Dickinson, USA). The sample was drawn into heparinised tubes, cooled in melting ice and centrifuged for 20 minutes at 2,400 revolutions per minute. The resultant plasma was removed by means of sterile Pasteur pipettes and stored in seven millilitre bottles in a deep freeze until being analysed for FFA and ketones. Ketone concentrations were determined using the distillation method of Reid (1960b) and the concentration of plasma FFA determined by the semi-automated method of Dalton and Kowalski (1967).

b) Group feeding trials

In addition large scale feeding trials were carried out concurrently with intake Experiments 1.1, 1.2, 2.1 and 2.2 with approximately 25 ewes in three pens, being offered diets identical to those described (see page 40). Totals of 30 kg of concentrate were not offered to ewes on hays 3) and 4) for previous investigations with hays 1 and 2) had indicated that this would not be necessary. Ewes were allocated to treatments on a basis of lambing date and body fat reserves, as measured by lumbar palpation (Russel *et al* 1969), at housing. Pens held seven to nine ewes which were housed eight weeks prior to parturition. Sheep were held in pens of approximately 15 square metres, with a trough space allowance of 0.4 metres per ewe

The hays on test were on free offer, with the concentrate fraction of the ration being supplied before 08:00 hours each day. Ewes had

Figure 3.7

Blood metabolites concentrations for ewes offered hay 1) plus four levels of concentrate

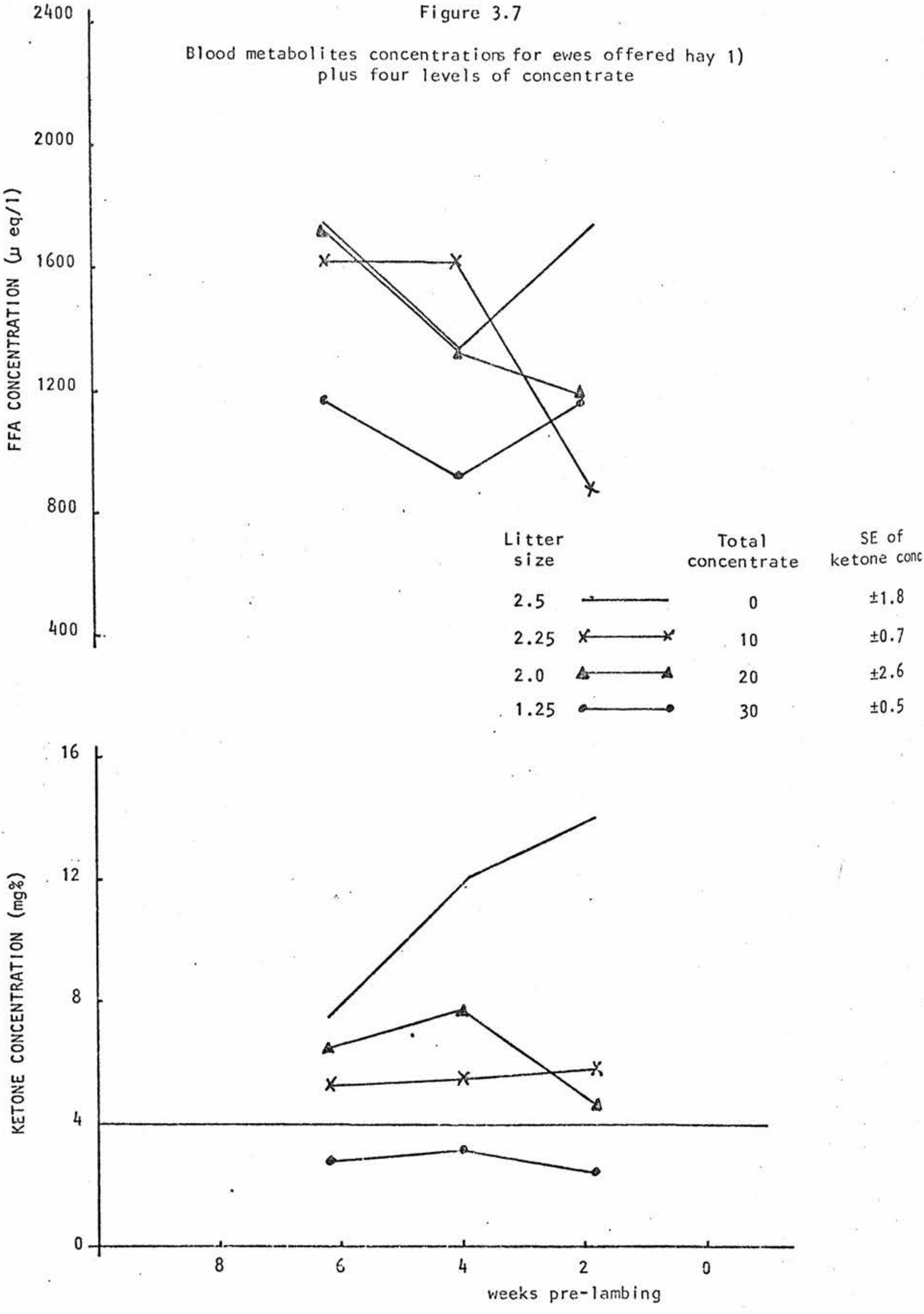


Figure 3.7A

Blood metabolites concentrations for ewes offered hay 1) plus four levels of concentrate

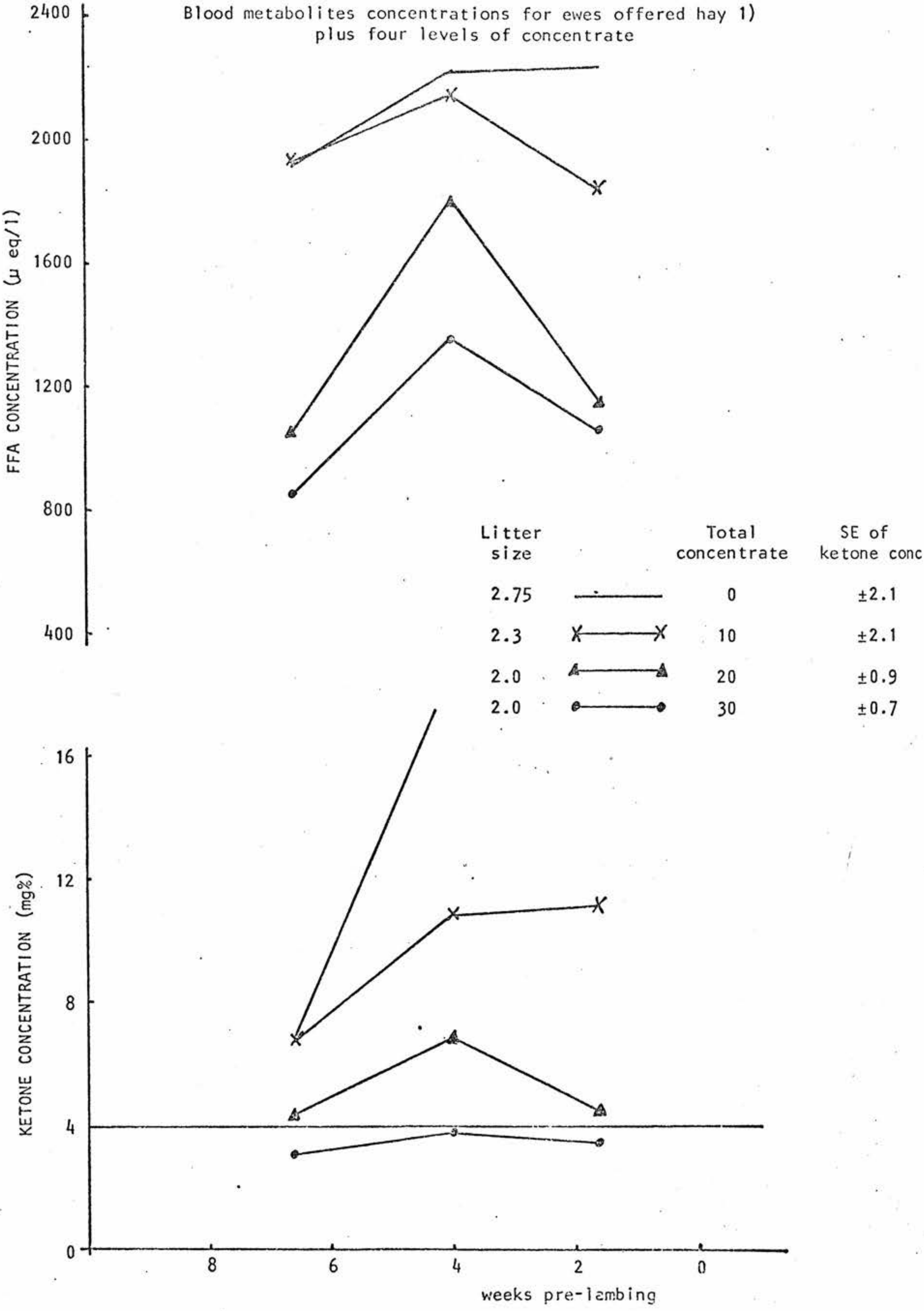


Figure 3.8

Blood metabolites concentrations for ewes offered hay 2) plus four levels of concentrate

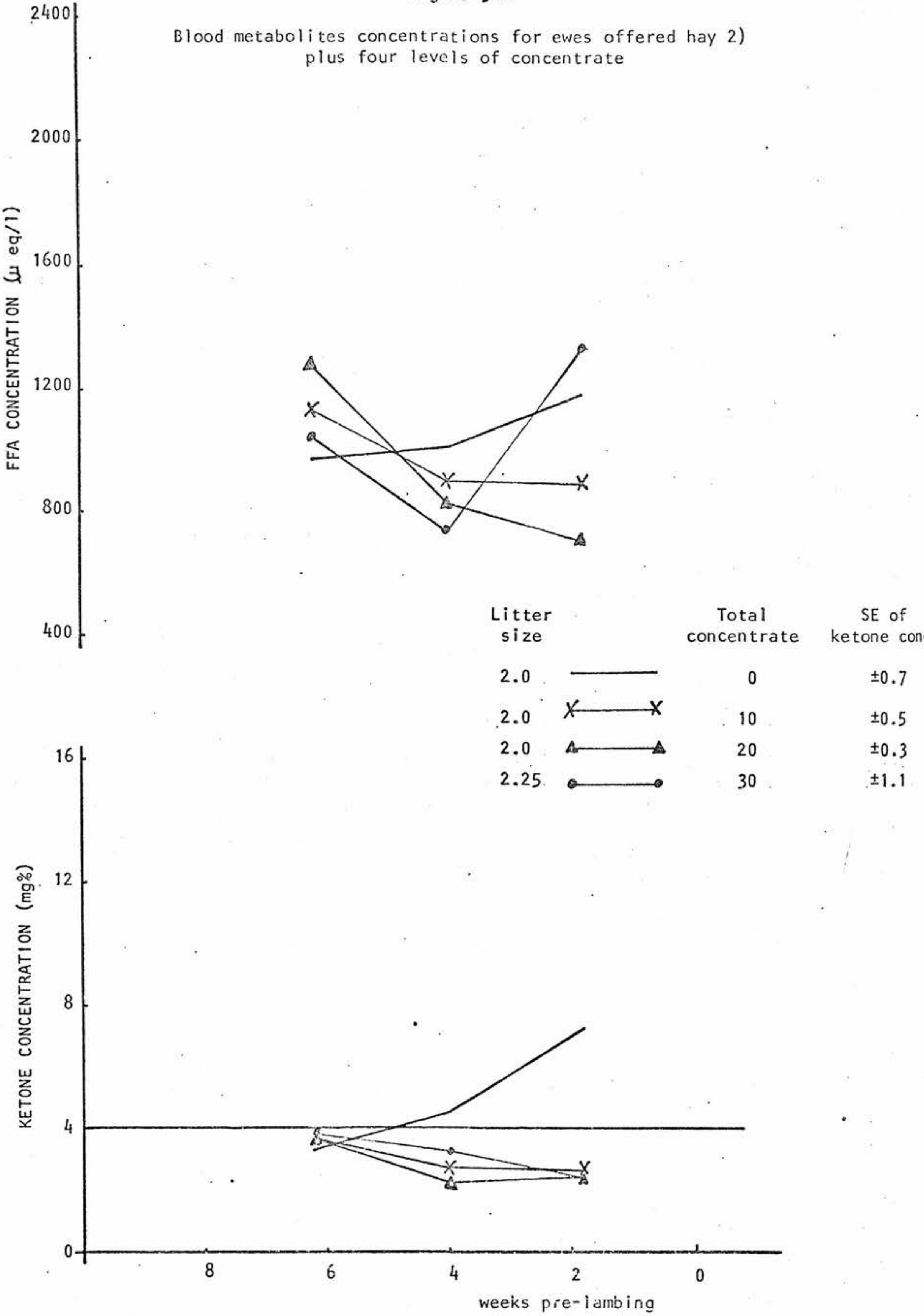


Figure 3.8A

Blood metabolites concentrations for ewes offered hay 2)
plus four levels of concentrate

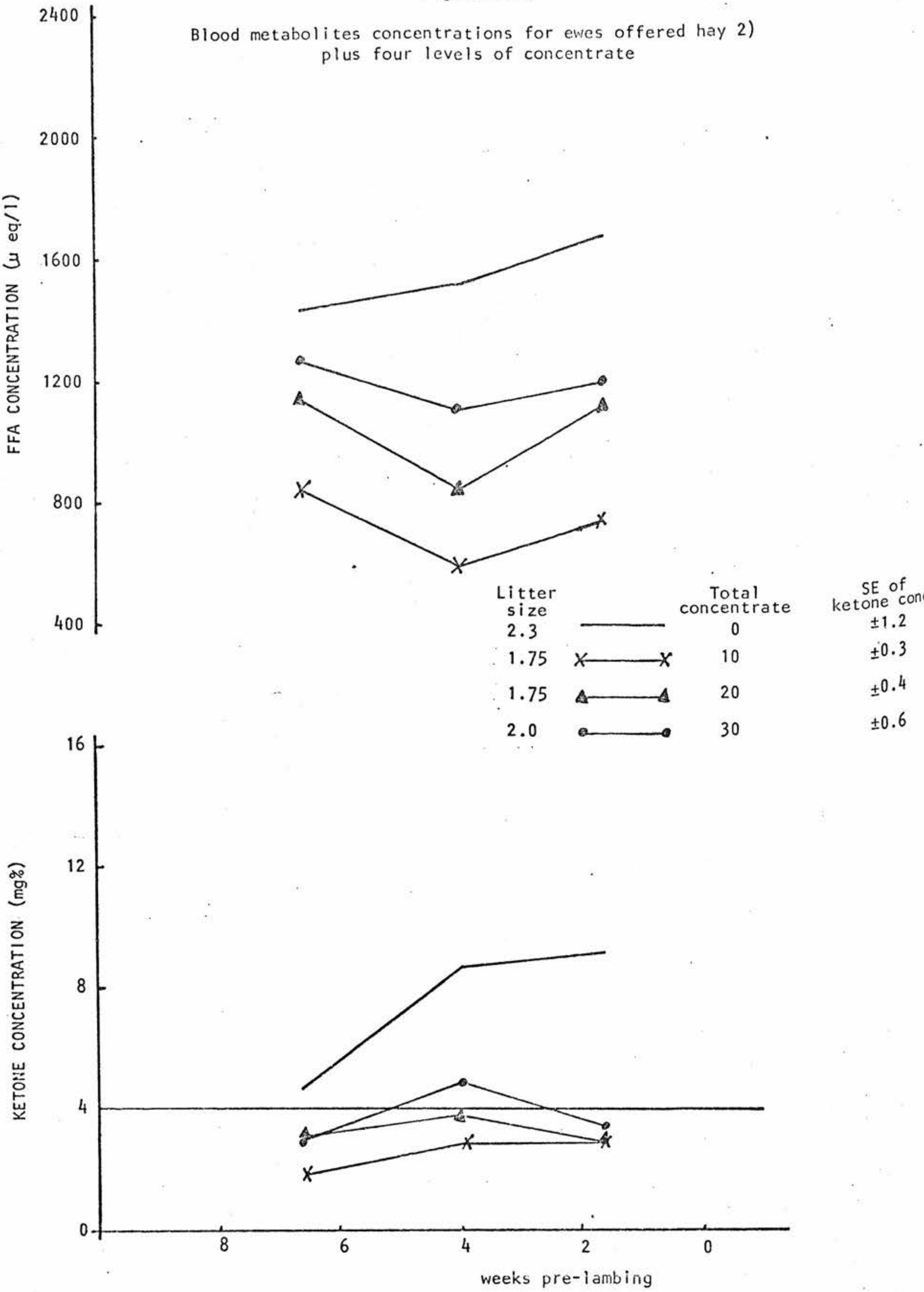


Figure 3.9

Blood metabolites concentrations for ewes offered hay 3) plus four levels of concentrate

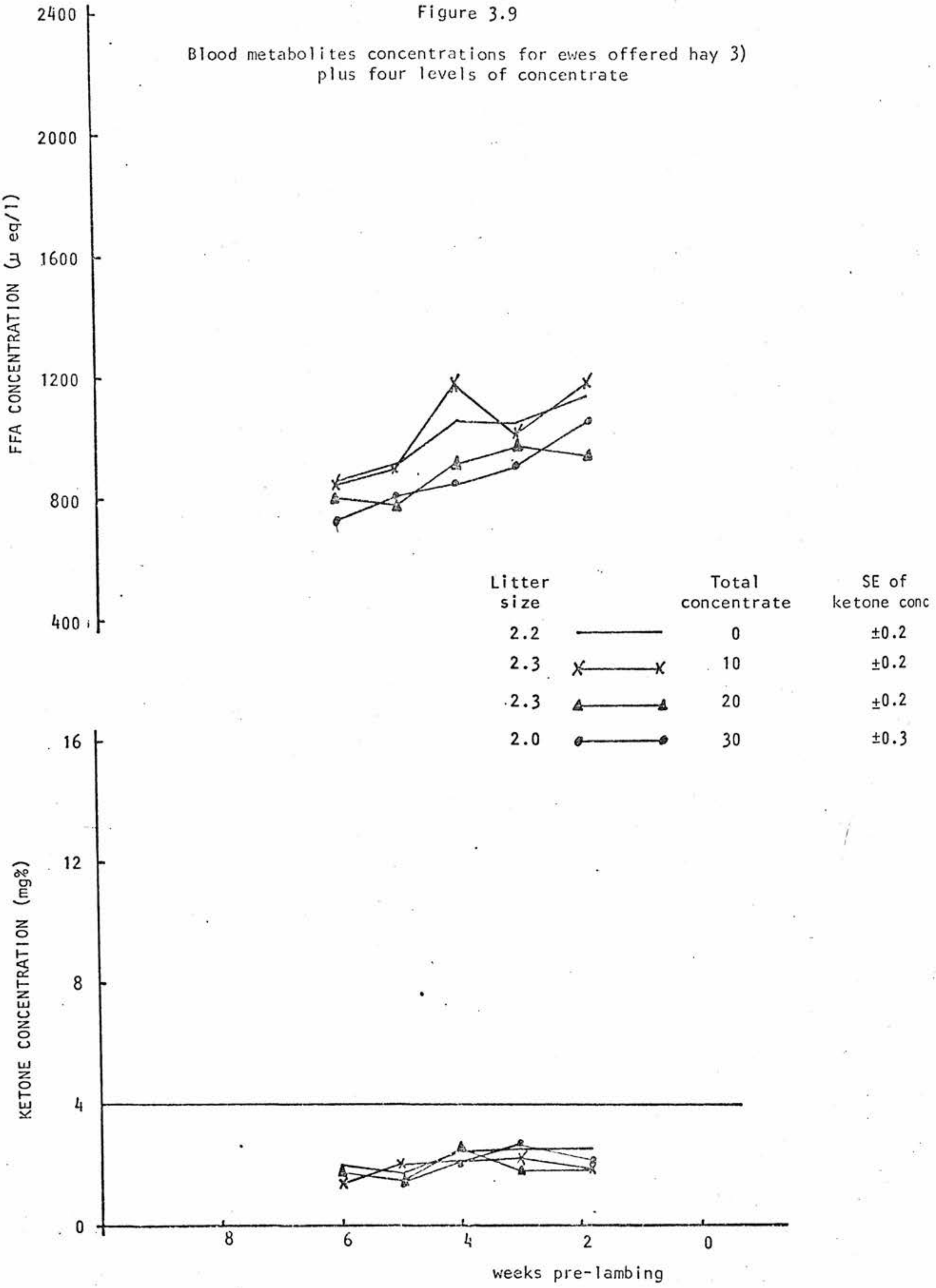


Figure 3.10

Blood metabolites concentrations for ewes offered hay 4) plus four levels of concentrate

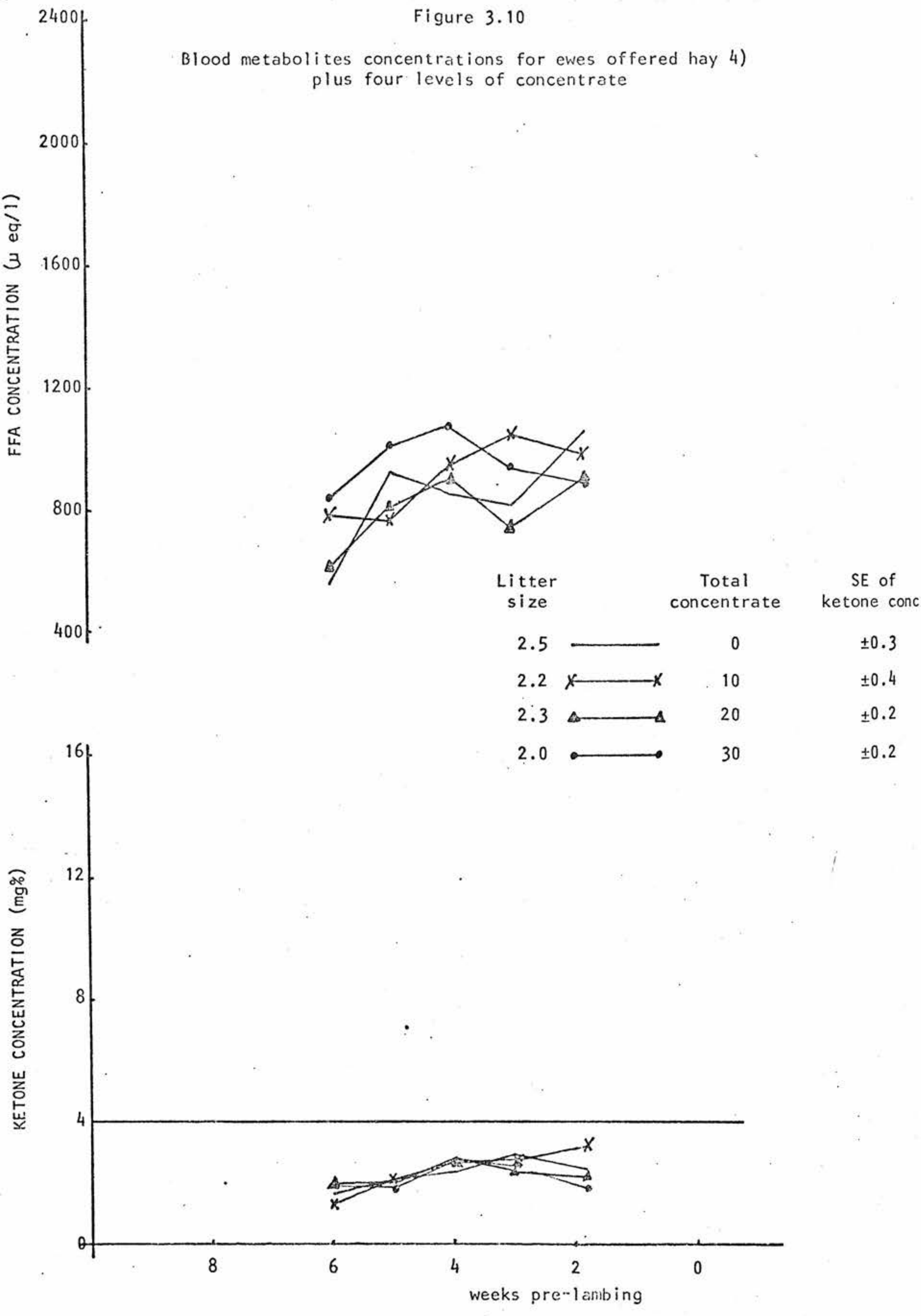


Figure 3.11

Blood metabolites concentrations for ewes offered hay 5) plus three levels of concentrate

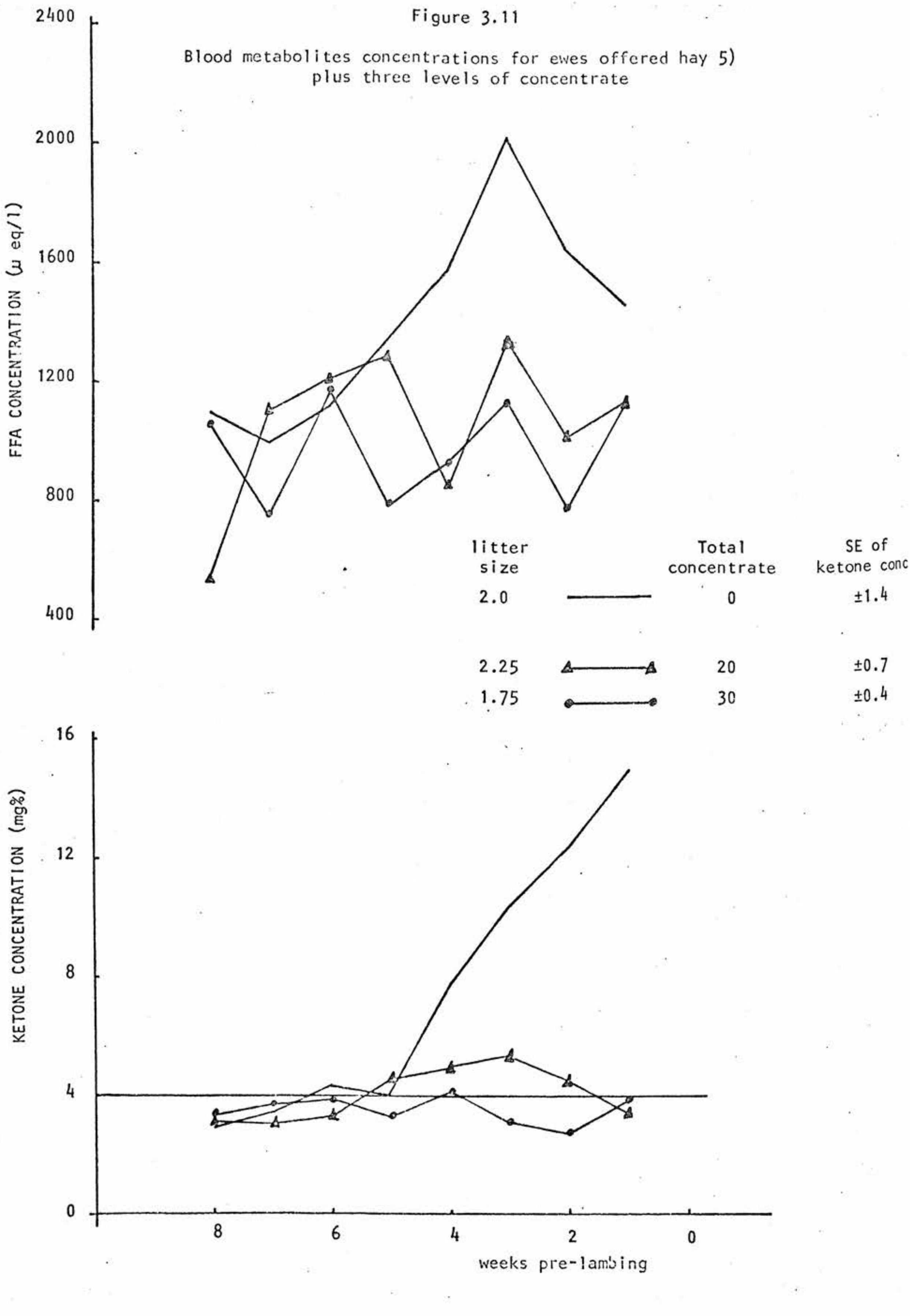


Figure 3.12

Blood metabolites concentrations for ewes offered hay 6)
plus four levels of concentrate

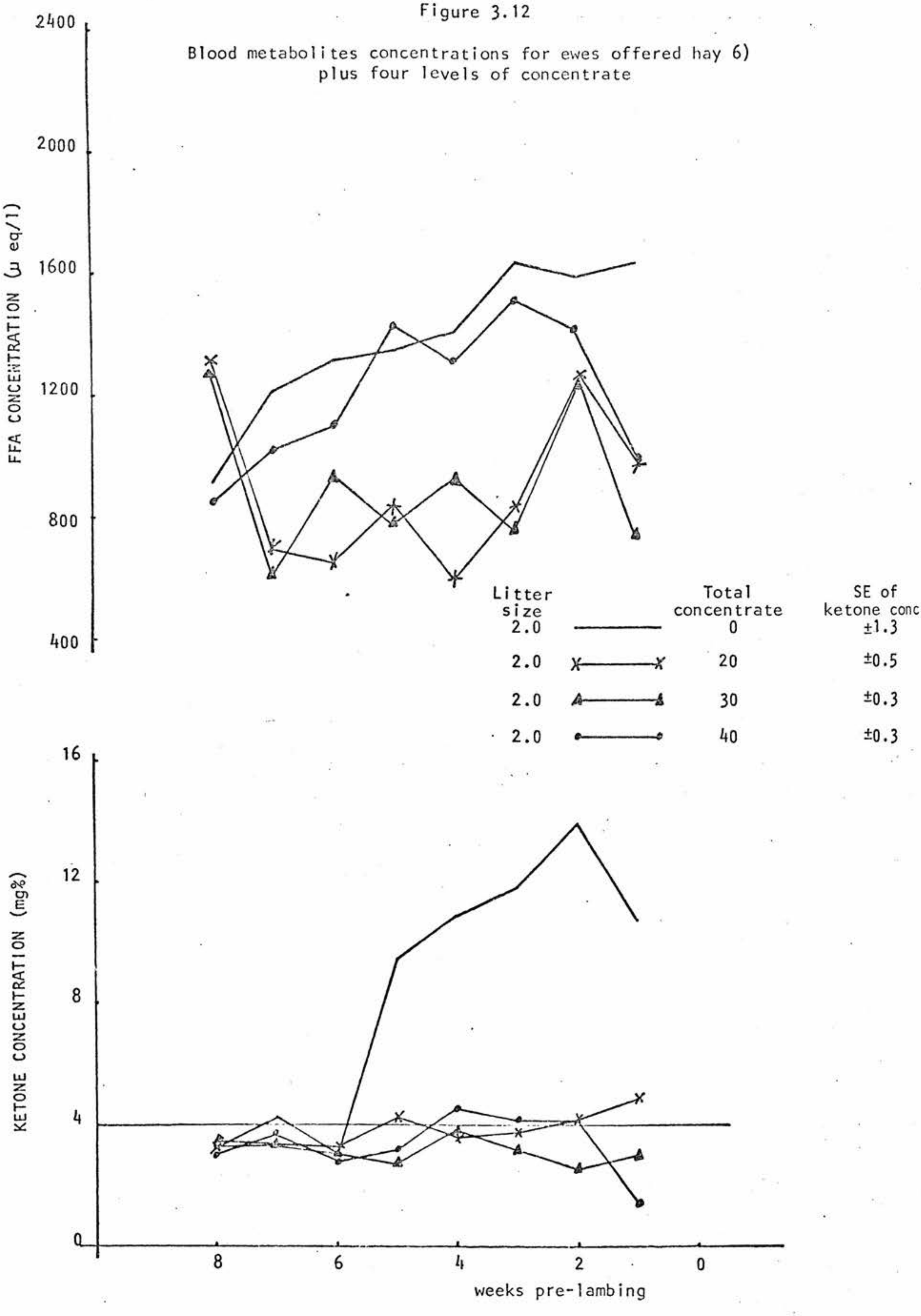
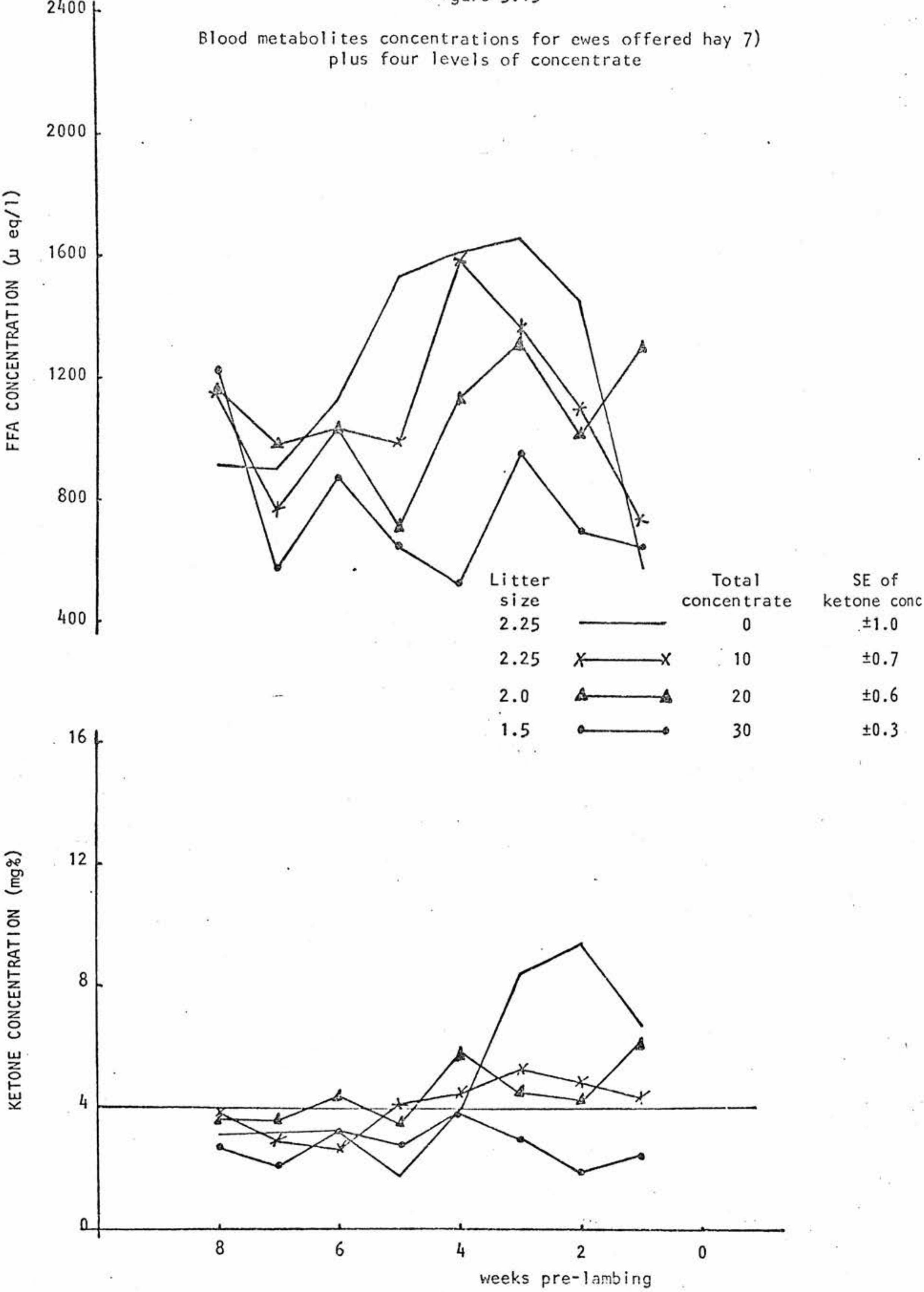


Figure 3.13

Blood metabolites concentrations for ewes offered hay 7) plus four levels of concentrate



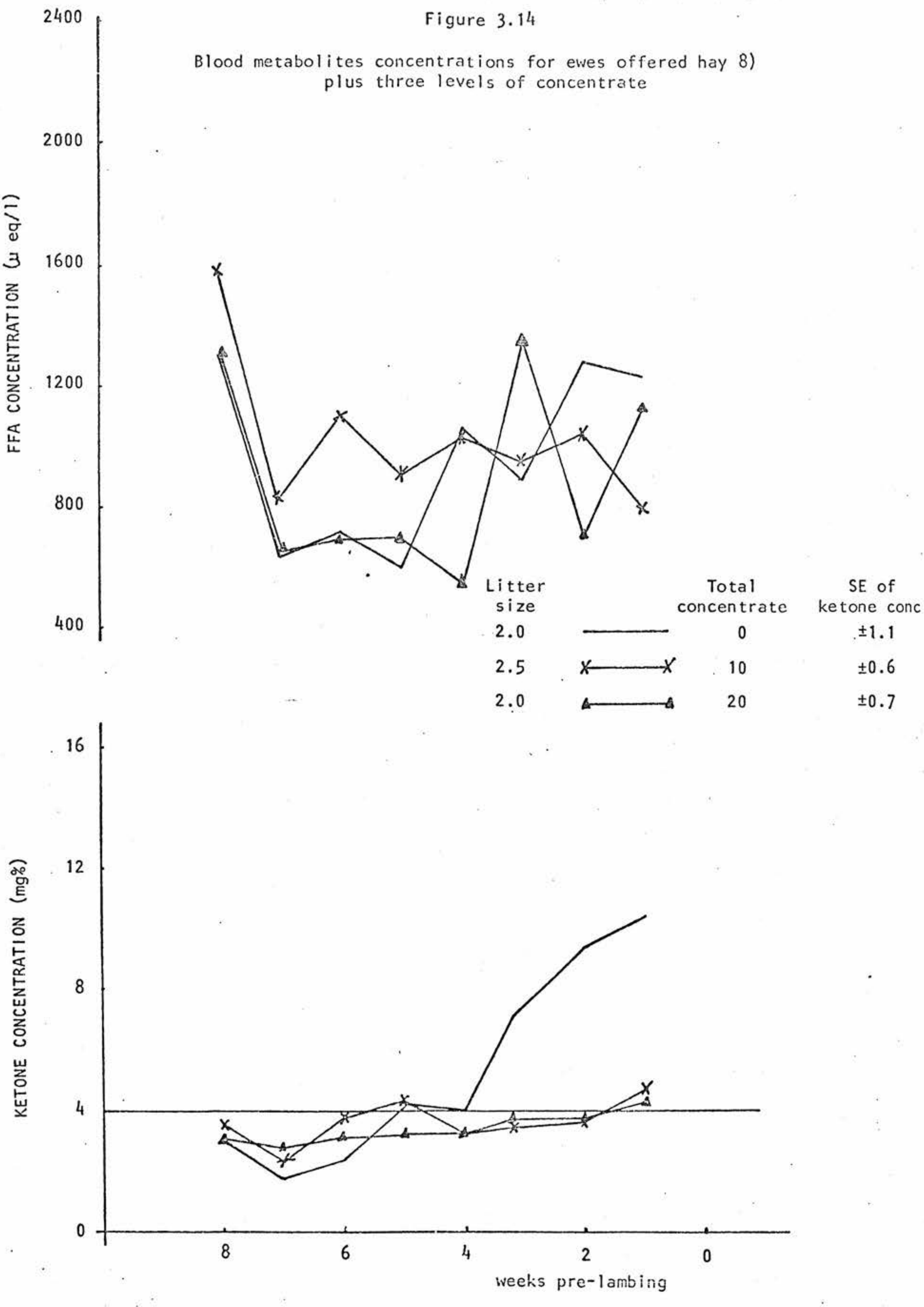



Figure 3.14

Blood metabolites concentrations for ewes offered hay 8) plus three levels of concentrate access to fresh water at all times, and wheat straw bedding supplied as required. Management and measurements made were essentially similar to those already described in the first and second experimental reports. Ewes were permitted to complete parturition in the feeding pens, and were then left in "mothering up" pens until lambs were considered fit to be turned out. Feeding and management post lambing was the same for ewes from all treatments. Ewes were fed concentrates, turnips and hay until sufficient grass was available.

The data from each treatment obtained on ewe weight changes, lamb weights at birth, and at two week intervals were subjected to analysis of variance (Snedecor 1956). Lamb weight gains to six weeks of age were calculated to obtain an estimate of milk yield from the ewes (Shrewsbury, Harper, Andrews and Zelle 1942; Shrewsbury, Andrews, Harper and Zelle 1943; Wallace 1948b; Barnicoat *et al* 1949b; Guyer and Dyer 1954; Owen 1955; Munro 1955; Burris and Baugus 1955; Barnicoat *et al* 1957c; Whiting, Slen and Bezeau 1958).

(iii) Results

a) Individual feeding trials

The mean levels of ketone and FFA measured in the ewes are presented in graphical form (see Figures 3.7 to 3.14), each figure indicating the mean concentrations of ketone and FFA determined with each hay and the levels of concentrate fed. The FFA concentrations failed to reflect the level of concentrate feeding, while the ketone levels proved more positive. The stage of gestation at which ketones exceeded 4 mg% varied with the quality of the forage eaten.

In 1972 hay 1) failed to provide sufficient nutrients to prevent serious depletion of body reserves from eight weeks prior to parturition. To compensate for the deficiency it was necessary to commence feeding concentrate eight weeks before lambing, and to offer the highest level of concentrate (30 kg) during the eight week feeding period (see Figure 3.7). By five weeks pre-partum ewes on hay 2) required the addition of concentrate supplement to maintain plasma ketones below 4 mg%. The addition of 10 to 20 kg of concentrate during the final six weeks of gestation prevented a rise in plasma ketones above 4 mg% (see Figure 3.8). These observations were confirmed by reference to blood samples drawn from similarly treated ewes on digestibility studies, with the indication that for hay 2) the 20 kg level of concentrate was necessary (see Figures 3.7A and 3.8A).

Studies on hays 3) and 4) in 1973 indicated that these forages alone when offered to appetite provided sufficient nutrients to keep plasma ketones below 4 mg%, although there was a trend of increase with time in the concentrations measured (see Figures 3.9 and 3.10).

Subsequent studies in 1974 with hays 5), 6), 7) and 8) emphasized that the point at which supplementation need commence was closely related to the quality of the forage on offer. With hays 5) and 6) supplementation with concentrates was required six to seven weeks prior to parturition, totals of 30 kg and 20 kg respectively being required (see Figures 3.11 and 3.12). Hays 7) and 8) proved adequate to provide sufficient nutrient until approximately four weeks prior to parturition (see Figures 3.13 and 3.14). The highest level of concentrate was necessary from four weeks until parturition for hay 7), and it has been calculated that approximately 20 kg of concentrate during the final four weeks of gestation would be adequate. For hay 8) the provision of 10 kg of concentrate during the final four weeks of gestation would prove adequate to prevent blood ketones exceeding 4 mg%.

Table 3.6

Percentage weight change from housing to
24 hours post-parturition

| Hays | Total concentrate supplied(kg) 30 | 20 | 10 | 0 |
|---|---|---|---|---|
| 1) | - 7.0 | -16.1 | -19.6 | -21.5 |
| 2) | - 3.8 | - 6.8 | - 7.3 | -11.6 |
| 3) | + 2.1 | + 0.4 | - 4.0 | - 7.6 |
| 4) | + 2.6 | + 3.6 | - 2.0 | - 3.1 |
| 5) | - 6.0 | -12.1 | - | -21.1 |
| 6) | -10.0 | - 8.5 | -13.4 | -16.0 |
| 7) | - 4.9 | - 8.5 | -11.6 | -19.7 |
| 8) | - | - 5.2 | - 9.6 | -11.4 |

Discussion and conclusions

Contrary to the reports by Russel *et al* (1967b), Sheehan and Lawlor (1972), Leat (1974) and Shevah (1974) the concentrations of FFA did not appear accurately to reflect the level of nutrition and are not considered in detail for this reason. The quantities of concentrate offered resulted in intakes of energy well below requirement (ARC 1965 plus Rattray *et al* 1974) of twin bearing ewes and probably caused the resultant rise in ketone levels (Russel 1968). Russel, Maxwell and Foot (1974) have found that prolonged minor under-nourishment is better reflected in plasma ketone concentrations, as experienced in these investigations.

Plasma ketone levels for ewes on trials in 1972 and 1973 were determined in the same batch, while ketone levels for those ewes on experiment in 1974 were analysed separately at a later date by the same method. FFA levels for all investigations were determined together. Ewes on the control diet (CRD) in 1973 had mean plasma ketone levels of 1.90 ±0.4 mg%, while those on the same diet in 1974 had mean plasma ketone levels (±SE) of 3.54 ±0.6 mg% - approximately 86% higher. The mean litter sizes were 2.1 and 2.0 respectively. On this basis hays 7) and 8) offered to appetite plus 10 kg of concentrate from four weeks pre-partum would be adequate. With hays 5) and 6) concentrate feeding need not commence until six weeks prior to parturition, requiring totals of 20 kg and 10 kg of concentrate respectively.

Moderate inroads in body reserves may also be measured in terms of weight change from the start of the feeding period until 24 hours post partum (Wallace 1948a; Thomson and Aitken 1959). The level of 4 mg% ketone in blood plasma corresponded approximately with a 6-10% loss in ewe body weight during the period considered (see Table 3.6). It is evident that as hay quality improved the amount of concentrate

Table 3.7

Total daily dry matter (kg) consumed by both individually and group penned ewes at three periods during the final eight weeks of gestation

| Hay | | Period I (6 weeks pre-lambing) | | Period II (4 weeks pre-lambing) | | Period III (1 week pre-lambing) | |
|---|---|---|---|---|---|---|---|
| | | individual | Group | individual | Group | individual | Group |
| 1 | + 10 | 0.97 | 0.98 | 1.10 | 1.00 | 1.30 | 1.40 |
| | 20 | 0.69 | 0.85 | 0.97 | 1.11 | 1.10 | 1.30 |
| | 30 | 0.86 | 0.92 | 1.15 | 1.35 | 1.38 | 1.47 |
| 2 | + 00 | 1.09 | 1.11 | 1.12 | 1.28 | 1.27 | 1.11 |
| | 10 | 1.14 | 1.07 | 1.13 | 1.27 | 1.47 | 1.26 |
| | 20 | 1.10 | 0.95 | 1.25 | 1.34 | 1.39 | 1.53 |
| | 30 | 1.15 | 1.02 | 1.42 | 1.46 | 1.47 | 1.49 |
| 3 | + 00 | 1.66 | 1.59 | 1.46 | 1.74 | 1.40 | 1.49 |
| | 10 | 1.48 | 1.50 | 1.55 | 1.60 | 1.58 | 1.71 |
| | 20 | 1.40 | 1.63 | 1.62 | 1.56 | 1.68 | 1.96 |
| 4 | + 00 | 1.67 | 1.79 | 1.70 | 1.82 | 1.62 | 1.90 |
| | 10 | 1.69 | 1.76 | 1.74 | 2.27 | 1.77 | 2.20 |
| | 20 | 1.78 | 1.70 | 1.75 | 1.99 | 1.70 | 1.99 |

required was reduced, and that for ewes carrying an average of two lambs it is beyond their intake capability to obtain sufficient nutrient from hay only when it is below an estimated metabolizable energy value of approximately 9.0 MJ per kilogram of dry matter. Forages of poorer quality result in excessive drawing upon body reserves.

The implications of the above results are considered more fully in the discussion following part (b) of this section.

b) Group feeding trials

1. Nutrient intake

Food intake was measured over two consecutive 24 hour periods each week, and the mean intake was considered to be the daily intake for that week. Some small amount of hay spillage was observed with the group fed ewes, resulting in the tendency to finding slightly higher total dry matter intakes over those measured with individually penned animals (see Table 3.7). The mean nutrient intakes of both individually penned and group fed animals were therefore similar.

Discussion and conclusion

The data of Foot and Russel (1971) and Russel, Maxwell and Foot (1974) have indicated that competition at feeding time resulted in a nutritional penalty to individuals in group fed sheep. Where concentrate feeding is at a low level competition results in "bully" ewes receiving twice to three times that of their more timid pen mates (Foot and Russel 1973; Foot, Russel, Maxwell and Morris 1973; Russel *et al* 1974), particularly with first pregnancy ewes (Foot *et al* 1973). When the concentrate allowance is increased competition is much reduced (Foot 1973). Competition at the feed box was kept to a minimum in the investigations here reported by ensuring adequate trough space.

Table 3.8

Lamb performance from group fed ewes

| Hay/concentrate level | | 1-10 | 1-20 | 1-30 | 2-00 | 2-10 |
|---|---|---|---|---|---|---|
| Birth weights (kg) | Singles | 5.22± 0.54 | 5.40± 0.95 | 5.85± 0.95 | 5.74± 0.34 | 5.75± 0.43 |
| | Twins | 3.90± 0.19 | 4.19± 0.20 | 4.55± 0.20 | 3.84± 0.22 | 4.42± 0.19 |
| | Triplets | 3.19± 0.39 | 3.35± 0.45 | 3.65± 0.45 | 2.72± 0.28 | 3.55± 0.49 |
| Perinatal mortality % | | 18.7 | 29.4 | 15.7 | 15.0 | 7.8 |
| Lamb daily live weight gain to six weeks (g) | Single | 383± 40 | 410± 50 | 375± 50 | 354± 20 | 361± 30 |
| | Twin | 270± 20 | 282± 20 | 287± 20 | 287± 20 | 289± 20 |
| Lamb weight at six weeks of age (kg) | Single | 20.92± 2.16 | 21.95± 2.49 | 21.19± 2.49 | 19.67± 1.11 | 20.13± 1.52 |
| | Twin | 15.34± 0.81 | 15.87± 0.93 | 16.32± 0.81 | 15.81± 0.99 | 16.38± 0.88 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2-20 | 2-30 | 3-00 | 3-10 | 3-20 | 4-00 | 4-10 | 4-20 |
| 5.25± 0.54 | 6.50± 0.95 | 4.86± 0.42 | 5.81± 0.47 | 5.20± 0.42 | 5.97± 0.42 | 6.17± 0.54 | 6.62± 0.47 |
| 4.71± 0.19 | 4.49± 0.24 | 4.24± 0.14 | 4.39± 0.13 | 4.48± 0.13 | 4.63± 0.12 | 4.90± 0.02 | 4.70± 0.03 |
| 3.84± 0.45 | 3.70± 0.28 | 3.37± 0.29 | 3.74± 0.29 | 4.50± 0.70 | 3.66± 0.32 | 2.72± 0.72 | 3.32± 0.70 |
| 20.9 | 22.4 | 9.7 | 10.2 | 6.7 | 8.4 | 10.1 | 8.5 |
| 382± 40 | 356± 60 | 363± 60 | 403± 30 | 417± 30 | 369± 30 | 394± 40 | 363± 30 |
| 314± 10 | 297± 20 | 305± 30 | 319± 30 | 325± 30 | 303± 30 | 327± 10 | 317± 30 |
| 20.65± 1.93 | 19.77± 3.05 | 19.81± 1.79 | 22.14± 1.79 | 22.92± 1.52 | 21.39± 1.63 | 22.44± 2.07 | 21.24± 1.79 |
| 17.80± 0.75 | 16.75± 0.77 | 17.02± 0.54 | 17.67± 0.51 | 18.22± 0.53 | 17.28± 0.48 | 18.48± 0.42 | 18.00± 0.49 |

Under the experimental conditions reported above the variation in nutrient intake of group fed ewes would be greatest with those ewes receiving totals of 10 or 20 kg of concentrate with hays 1) or 2) to appetite. These hays were of poor feed value and would not compensate for variations in concentrate intake. Such a conclusion is supported by the observation of Foot *et al* (1973) that the better the basal forage quality the less important was the variation in concentrate intake when ewes were group fed.

2. Ewe and lamb performance

The diet supplying hay 1) alone to pregnant ewes was abandoned approximately three weeks prior to parturition, for ewes were judged in a condition (score ≤1.5 {Russel *et al* 1969}) likely to result in high ewe mortality. Ketone levels were in excess of 5 mg% at this time.

The quantity of concentrate had no effect upon the birth weight of single lambs produced to ewes fed on the four hays examined {hays 1) to 4)}. Ewes fed on hay 1) produced twin lambs of mean birth weight which increased with the level of concentrate offered, but significant differences ($P<0.05$) were only measured between those ewes offered totals of 10 and 30 kg of concentrate (see Table 3.8). With hay 2) the addition of concentrates significantly affected ($P<0.05$) the birth weight of twin lambs, but an increase in the quantity to above 10 kg over the final eight weeks of pregnancy had no significant effect upon lamb birth weight. Concentrate levels had no significant effect upon the birth weight of twin lambs produced by ewes fed on hays 3) and 4), there being a trend of increasing birth weight with the level of concentrate offered with hay 3). The quality of hay affected the mean birth weight of twin lambs in each year, but only achieved significance ($P<0.01$) when comparing hays 3) and 4). The numbers of ewes producing triplets were insufficient to show significant

Table 3.9

Performance of group fed ewes

| Hay/concentrate level | 1-10 | 1-20 | 1-30 | 2-00 | 2-10 |
|---|---|---|---|---|---|
| Litter size | 2.11 | 2.32 | 2.14 | 1.96 | 1.96 |
| Lambs suckled | 1.81 | 1.76 | 1.62 | 1.42 | 1.62 |
| % ewe body weight change from housing to 24 hours after lambing | -13.9± 4.6 | -13.8± 5.0 | -7.4± 4.8 | -15.0± 5.2 | -11.0± 4.8 |
| % ewe body score reduction from housing to 24 hours after lambing (twin bearing only) | 31 | 30 | 29 | 37 | 36 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2-20 | 2-30 | 3-00 | 3-10 | 3-20 | 4-00 | 4-10 | 4-20 |
| 2.13 | 2.29 | 2.07 | 2.11 | 1.87 | 1.96 | 1.97 | 1.97 |
| 1.75 | 1.77 | 2.00 | 2.00 | 1.79 | 1.93 | 1.88 | 1.93 |
| -6.8 ± 4.4 | -7.6 ± 4.6 | -5.8 ± 3.2 | -4.1 ± 3.0 | +0.4 ± 3.1 | -1.9 ± 2.9 | +2.3 ± 2.6 | +2.3 ± 2.6 |
| 27 | 31 | 28 | 21 | 17 | 18 | 17 | 6 |

effects of the level of concentrate feeding upon birth weights of their lambs. With hays 1) and 2) high levels of concentrate feeding increased birth weights, except for a total of 30 kg of concentrate with hay 2).

Table 3.8 also shows the amount of lamb mortality experienced on each hay tested. The level of concentrate feeding failed to affect the mortality of lambs in the two years of experiment. In the second year of investigation (1973) mortality was much reduced.

Post natal lamb performance, as measured by lamb growth to six weeks of age (see Table 3.8), indicated that the levels of nutrition in late pregnancy did not affect subsequent milk yield. Ewes offered hay 2) during late pregnancy had heavier twin lambs at six weeks after lambing than those offered hay 1), but failed to reach significance at even the $P<0.05$ level. Such a difference is not apparent between ewes offered hays 3) and 4) during late pregnancy.

The degree of under-nourishment of ewes on experiment was measured by the percentage weight and condition score change from mid-pregnancy to 24 hours post partum (see Table 3.9). The level of concentrate offered governed the degree of weight and condition score change, and analysis of covariance indicated that both litter size and litter weight significantly affected ($P<0.001$) maternal body weight change from mid-pregnancy to 24 hours post parturition. Ewes bearing twin lambs lost approximately 5 kg more body weight than their single-bearing counterparts, and each extra kilogram of lamb at birth reduced ewe weight by 1.4 kg.

## Discussion and conclusions

To significantly affect lamb birth weight and subsequent performance it is necessary to under-nourish the pregnant ewe to a relatively serious degree (see page 54). The levels of concentrate feed offered with each hay tested supplied a wide range of daily nutrient intakes (see Tables 3.3 and 3.4), particularly during the final three weeks of pregnancy. It is therefore to be expected that the levels of nutrition experienced would have some measurable effect upon lamb birth weight (see Table 3.8). The lack of effect of nutrition upon the birth weight of single lambs while having some small effect on that of twins and triplets at these levels of feed is in agreement with the data of Wallace (1948a), Thomson and Thomson (1949), Coop (1950), Pálsson and Vergés (1952) and Sheehan and Lawlor (1972), indicating that substantial under-nourishment may be tolerated by the pregnant ewe.

Lamb mortality has been observed to be influenced by the level of ewe nutrition in late pregnancy (Bell 1944; Wallace 1948a; Thomson and Thomson 1949, 1953; Harris, Cok, Stoddart and Marsen 1950; Jordan 1952; Thomson 1952; Evans and Wilcox 1969; Booth 1972; Thurley 1972) through the reduction in lamb size (Venkatachalan, Nelson, Thorp, Luecke and Gray 1949; Thomson 1952; Alexander, McCance and Watson 1955) and the shortening of the gestation period (Alexander 1956; Dawes and Parry 1965). Similar to the findings of Underwood and Shier (1942), Coop (1950) and Duncan (1973), the level of concentrate feeding in the trials here reported had no effect upon lamb mortality.

When testing hays 1) and 2) in 1972 the problem of delayed onset of lactation was experienced on all treatments, but detailed records of milk availability at parturition were not made. The investigations on hays 3) and 4) in 1973 included an assessment of the timing of the onset of lactation and the adequacy of milk produced at parturition. However, all ewes on experiment had adequate milk at parturition. Mean litter sizes in both years were similar, and lamb birth weights in the second year were similar to those of lambs born to ewes fed on hay 2). It is suggested that the lower lamb mortality observed in the second year was due to a greater milk availability at parturition. Such observations are in agreement with those of Thomson and Thomson (1949, 1953).

The lack of milk at parturition on all treatments having hays 1) or 2) as basal forage, was similar to that observed at Edinburgh University in previous years when higher levels of a similar concentrate were on offer (Duncan personal communication), and in 1974 when groups of ewes were offered either complete ruminant diet to appetite or diets based upon hays 5) and 6). The inference that the amount of feeding in late pregnancy will affect the availability of milk at parturition (Wallace 1948a; Thomson and Thomson 1953; Guyer and Dyer 1954; Peart 1967a; Treacher 1970) may therefore not be completely accurate. Broster, Foot and Line (1966) found that the effect of steaming up of dairy cows prior to calving was dependent upon forage quality. It is therefore concluded that the level of nutrition of the ewe in late pregnancy, coupled with the basal forage quality, will affect the onset of lactation.

An appendix summarises and discusses ewe and lamb health.

Post natal lamb performance (see Table 3.8) suggests that the nutrient intakes achieved in late pregnancy on the various diets had little or no effect upon ewe milk yield. The data are in agreement with the observations of Coop (1950), Guyer and Dyer (1954), Papadopoulos and Robinson (1957), Duncan (1973) and Shevah (1974) that when ewes receive less than nutrient requirement during late pregnancy, but with little effect upon lamb birth weight, subsequent lamb performance is not reduced. According to Peart (1968b) leaner ewes are more efficient than fat ewes for milk production, and may partly account for the similarity of lamb performance from all treatments.

Weight changes measured in ewes (see Table 3.9) do not take into account the changes in weight due to plasma volume increase (Wallace 1948b;

Rattray *et al* 1974), mammary tissue development (Wallace 1948b; Guyer and Dyer 1954) or uterine size (Wallace 1948b; Langlands and Sutherland 1968; Rattray *et al* 1974). The percentage change in body score (Russel *et al* 1969) over the feeding period indicates that some drawing upon body reserves took place despite an increase in total maternal body weight (see Table 3.9). Although body scoring is dependent upon operator skill and repeatability, in each year body score and weight changes of the same magnitude were reported.

It has been demonstrated that both energy (Russel *et al* 1967a; Russel and Eadie 1968; Langlands and Sutherland 1968; Robinson *et al* 1971; Meat and Livestock Commission 1973; Rattray *et al* 1974) and protein (Agricultural Research Council 1965; Lodge 1972; Meat and Livestock Commission 1973) requirements increase as pregnancy advances. Standard advice to farmers recommends a gradual increase in the nutrient level during the final weeks of pregnancy (North of Scotland College of Agriculture 1958; 1972; Ministry of Agriculture, Fisheries and Food 1964; West of Scotland College of Agriculture 1969). However, the satisfactory performance of lambs from ewes fed on hays 3) and 4) alone, when nutrient intake dropped slightly during late pregnancy (see Tables 3.4 and 3.5), suggests that the pattern of nutrient intake is not of prime importance.

The data of Elsley, Bathurst, Bracewell, Cunningham, Dent, Dodsworth, MacPherson and Walker (1971) obtained from pregnant sows indicated that the pattern of supplying the feed had no effect either upon the number or weight of pigs born, or upon subsequent performance, and they concluded that the total, rather than the pattern of feed was the important factor. Rutter (personal communication) did not observe any effect of the pattern of late pregnancy concentrate feeding upon ewe or lamb performance when he offered pregnant ewes a total of 25 kg of concentrate in ascending, descending and constant levels during the final six weeks of pregnancy.

Pond, Dunn, Wellington, Stouffer and Van Vleck (1968), Pond, Wagner, Dunn and Walker (1968) and Pond, Strachan, Sinha, Walker, Dunn and Beames (1969) report that sows fed on protein free diets in late pregnancy produced similar numbers and weights of pigs at birth and weaning, and draw attention to the buffering ability for protein of the pregnant sow. Robinson *et al* (1971) confirmed the ability of the ewe to draw upon body reserves of protein in late pregnancy without detriment to future performance, and reported an enhanced nitrogen retention associated with pregnancy.

The pattern of supplying nutrient, the level of feeding necessary in late pregnancy for adequate performance and the extent to which the pregnant ewe may draw upon body reserves requires further investigation.

Both the data presented and the information available in the literature reveal that the ewe may, without detriment to subsequent production, draw upon body reserves to produce her lambs. The theoretical late pregnancy nutrient requirement and that quantity of nutrient necessary for satisfactory performance are therefore quite different. From the blood analysis, energy and protein intake and production data presented above it is possible to determine (from Tables 3.4 and 3.5) the approximate energy and protein necessary for a 70 to 80 kg ewe to produce strong twin lambs and subsequent satisfactory growth rates. The energy levels are (MJ per day):

| day 56-40 | day 39-23 | day 22-parturition |
|---|---|---|
| 9.0 | 11.0 | 14.0 |

and the corresponding quantities of crude protein are (CP):

| day 56-40 | day 39-23 | | day 22-parturition |
|---|---|---|---|
| 90 | 115 | and | 150 g per day |

With reference to these estimates of energy and protein intake necessary to give satisfactory performance, it can be calculated, using the equations derived above (see page 65), that the forage quality required, if no concentrates are to be fed, at the three stages of pregnancy are as follows:

| | *In vitro* organic matter digestibility % | Crude protein (%) | Estimated metabolizable energy (MJ/kgDM) |
|---|---|---|---|
| Stage I | 51.7 | 8.3 | 7.8 |
| Stage II | 54.9 | 9.1 | 8.4 |
| Stage III | 62.2 | 11.2 | 9.8 |

Consideration of ewe nutrient requirement in late pregnancy has been restricted to multiple bearing ewes. It was evident that those ewes carrying single lambs were sufficiently well nourished to produce that lamb on *ad libitum* hay, with the possible exception of hay 1) alone. Condition scoring of ewes prior to the normal steaming up period would indicate the thinner and possibly twin-bearing ewes which should be offered extra feeding. A similar exercise some three weeks prior to projected lambing date would permit the selection of ewes in poor body condition for preferential treatment.

There are further practical implications from the consideration of the data presented. It has been demonstrated that with hays of average quality or better, concentrate may be saved during late pregnancy, leaving the feed available for higher levels and/or prolonging of feeding during early lactation, for feeding in early lactation controls the total milk yield of ewes (Barnicoat *et al* 1949a; Coop 1950; Barnicoat *et al* 1957a; Papadopoulos and Robinson 1957; Munro 1962; Peart 1967a; 1967b, 1968a, 1970). It is to be postulated therefore that such a system of management would make more efficient use of the available concentrate feed.

Campling (1966d), Murdoch (1967) and Edwards (1973a) draw attention to the phenomenon of the existence of different controls of intake for silage and hays, despite a general relationship between intake and digestibility. Campling and Murdoch (1966) and Edwards (1973a) consider that silage intake is controlled by the percentage dry matter of the silage. Silage as a feed for pregnant ewes has been widely reported (e.g. Cooper 1966; Forbes, Rees and Boaz 1967; Forbes 1970a; Rutter, Laird and Broadbent 1971; Sheehan and Lawlor 1972), but only Sheehan and Lawlor (1972) have set out in a limited manner to test the value of grass silage as feeds for ewes in late pregnancy. According to Morgan (personal communication) silage (in England) is on average eight units of starch equivalent better than hay. The data of Edwards (1973b) indicates that the difference in the east of Scotland is ten units of starch equivalent in favour of silage. It is therefore to be expected that ewes fed on high dry matter silage would require even less concentrate supplement than those fed on hay. Further work of a similar nature to the trials described above could be profitably undertaken to determine the amounts of silage of different quality and concentrate necessary to provide sufficient nutrient for adequate performance.

The work described above was carried out upon ewes which were housed during the period of test. Maintenance requirements of housed ewes (Langlands, Corbett, McDonald and Pullar 1963) proved to be 24% less than grazing ewes (Langlands, Corbett, McDonald and Reid 1963).

Coop and Hill (1962) suggest that the requirement of grazing sheep is 34% above that of similar pen fed animals (Coop 1962b). A figure of 22% less nutrient requirement for pen fed sheep is suggested by Jagusch and Coop (1971).

The data of Langlands, Corbett, McDonald and Pullar (1963) and Langlands, Corbett, McDonald and Reid (1963) were obtained on shorn sheep, and shearing has been shown to increase heat output and subsequently affect nutrient requirement (Blaxter, Graham and Wainman 1959). Part of the difference of nutrient requirement between housed and grazing sheep observed by Langlands and co-workers may be cancelled by the presence of a full fleece. Clapperton (1961) suggests 10% additional energy over maintenance for motion. It is debatable as to whether the nutrient required for the products of conception is to be considered greater when pregnant ewes are in the field. The extra maintenance for ewes similar to those kept outside would amount to a further 2 MJ per day (allowing 24% extra for maintenance for ewes outside {Langlands, Corbett, McDonald and Reid 1963} and 8.3 MJ per day for maintenance {ARC 1965}). A further 150 g of concentrate per day would supply the extra nutrient, or commencing feeding of concentrate earlier when necessary. However, the extra nutrient required may be wholly or partially derived from the increase in voluntary intake brought about by exposure (Weston 1970).

# SECTION IV

## DISCUSSION AND CONCLUSIONS

## Discussion and conclusions

Both Crampton (1957) and Raymond (1969) stress the significance of voluntary intake as a quality factor in evaluating forages, and Bonnecarrère (1973) suggested an index of forage quality consisting of a combination of some measure of fibrousness with a measure of digestibility or rate of digestion of this component may be useful. From the intake trials reported above it is possible to discern a positive relationship ($r$ = 0.8) between dry matter intakes by ewes in late pregnancy and hay quality as measured in the laboratory by estimating hay metabolizable energy (MJ per kg DM), which includes a measurement of forage fibre and crude protein content (Alderman *et al* 1966). However, *in vitro* organic matter digestibility of the forages gave a more accurate prediction of voluntary forage intake by ewes in late pregnancy ($r$ = 0.9) and the subsequent potential feed value of the hay. It is possible that the routine determination of forage *in vitro* organic matter digestibility would give a better index of hay quality than estimated metabolizable energy content of forage for ewes in late pregnancy.

In Section III it has been demonstrated that in late pregnancy the forage quality governed intake of nutrient and the nutrient availability per unit of dry matter. Thus, according to Blaxter *et al* (1961) the "most important corollary is that an increase in the digestibility of a fodder from, for example, 50 to 55% is not to be interpreted as an improvement of 10% in the value of the food". By increasing hay *in vitro* organic matter digestibility from 50 to 55% in stage I of the feeding period energy intake was increased by 32.7%, in stage II by 28.5% and in stage III by 27.5% (using equations derived on page 65). Figures such as these provide illustration of the potential benefits to

Table 4.1

Concentrate necessary for a 70 to 80 kg ewe bearing twin lambs

| Hay quality | Energy concentration of hay (MJ ME/kg DM) | Total hay likely to be eaten in 8 weeks (kg) | Total concentrate (kg) | Daily concentrate requirement (g) weeks pre-partum | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| Very poor | ≤ 7.7 | 50 | 32 | 150 | 150 | 450 | 450 | 675 | 900 | 900 | 900 |
| Average | 7.8 - 8.4 | 75 | 17.5 | - | - | 100 | 300 | 300 | 600 | 600 | 600 |
| Above average | 8.5 - 9.7 | 85 | 7.5 | - | - | - | - | 150 | 300 | 300 | 300 |
| Excellent | ≥ 9.8 | 105 | - | - | - | - | - | - | - | - | - |

the agricultural community of making superior quality forage and should be part of the advisory service message.

Regular blood sampling for ketone levels demonstrated that the quality of hay, and its voluntary intake governed the requirement for concentrate feed, both in time of commencement of feeding and in terms of total quantity fed pre-partum. It was also evident, that even with the best quality hays and the highest level of concentrate employed (30 kg per ewe per eight weeks), the calculated nutrient requirements for the final week of pregnancy (19.8 MJ ME per day {ARC 1965 plus Rattray *et al* 1974} and 250 g CP per day {Meat and Livestock Commission 1973}) to avoid negative nutrient balance were not satisfied. However, these data demonstrated that moderate reductions in body reserves during late pregnancy were permissable. It is therefore impractical in biological terms and unwise in economic terms to attempt to supply sufficient food to the pregnant ewe to satisfy theoretical nutrient requirements, especially where the basal forage is of poor quality. It is unlikely that where conventional feeds are used that nutrient requirements of late pregnancy will be met, for Duncan (1973) found that *ad libitum* feeding of barley based concentrates was insufficient to meet these requirements.

The data presented above make it possible to recommend the quantities of hay of different quality and the amount of concentrate required by the ewe carrying twins (in body condition 2.5 to 3.5) during late pregnancy to produce satisfactory performance without drawing to any detrimental extent upon body reserves (see Table 4.1). It may be necessary to allow for spillage of hay, but this will depend upon the method of feeding employed. Thinner ewes may require further concentrate feeding.

In Appendix I it is concluded that the mean starch equivalent (SE) of hays made in Britain approximates to 36 (SE of 35 ≡ 8.3 MJ ME per kg DM {Morgan 1973}). On the basis of the concentrate levels necessary for satisfactory performance of ewes set out in Table 4.1, the survey information about hay quality indicates that on average 50% or over of hays made in Britain are of sufficiently good quality to provide considerable savings in the quantity of concentrate offered, compared with the Meat and Livestock Commission figures or to the standard advisory recommendations.

There are wide practical and financial implications stemming from the recommendations contained in Table 4.1. When considered in conjunction with the observations of the Meat and Livestock Commission (Kilkenny personal communication) that 44.0 kg of concentrate are fed (in 1974) to ewes in late pregnancy the indications are that when hay is above average quality, 30 kg or more of concentrate may be saved. Costing concentrate at £70 per tonne the potential saving is £3.08 per ewe when hays are of better quality than 9.8 MJ of ME per kg of DM. More hay would be consumed to achieve fill, worth approximately £1.00 (costed at £50 per tonne). The net saving would be in the region of £2.00 per ewe. When hays are of medium quality or better (>8.4 MJ per kg DM) the saving would be approximately £1.00 per ewe. If hays were costed at £25 per tonne (as is more normal) the saving would be increased by £0.5 per ewe.

At the December 1972 census the total breeding flock (excluding ewe lambs put to the ram) in the United Kingdom numbered some 12.4 million ewes, approximately 40% of which were lowland ewes (National Economic Development Office 1974). If it were possible to provide hays of 9.8 MJ per kg DM, and assuming that the figure of 44.0 kg (Kilkenny personal communication) of concentrate per ewe is repeated on a nation-wide basis for lowland ewes, there is a potential saving to the industry in concentrates of the order of 200,000 tonnes, worth £14,000,000. Where hays of medium quality are fed on a national basis the saving would be £7,000,000.

When above average hays are on *ad libitum* offer total concentrate requirement is of the order of 10 to 15 kg during the final six weeks of pregnancy. Studies indicated that a ration of 300 g (fresh weight) of barley based concentrate per day is unlikely to affect hay intakes, and Rutter's studies (personal communication) suggested that constant levels of concentrate throughout the late pregnancy period had no effect upon ewe or lamb performance. There is, therefore, the implication that with hays of average or above average quality ewes should receive a ration of 300 g of concentrate each day during the final six weeks of pregnancy to permit the maximum intake of nutrient from forage, and thus make the best use of the available roughage. Further studies on this topic are necessary in the hope that they might prove profitable by making the management easier and making better use of forage.

The above investigations have provided the basis for advising on the quantity and timing of concentrate necessary during late pregnancy when ewes are offered hay to appetite for satisfactory ewe and lamb performance. The possible financial benefits accruing from the adoption of concentrate rationing based upon a knowledge of the potential feed value of a hay have been stressed. Dissemination of the information and reasoning behind the recommendations contained in Table 4.1 would necessitate an advisory effort, perhaps initially in leaflet form, to stress that, as with dairy cattle, the better the quality of the hay fed to pregnant sheep the greater is the nutrient consumed. The above data provide figures, which may be quoted, of nutrient consumption for the 70 to 80 kg ewe carrying twins.

The recommendations contained in Table 4.1 are of little use without an estimate of hay quality. It will be necessary to ensure that the sheep farmer samples the available hay and obtains appropriate chemical analysis for the best prediction of feed value. Instruction on sampling technique, or sampling by a professional or adviser may be required. Based upon careful sampling and chemical analysis of the hays available it will now be possible for the adviser to provide a feeding stratagem for the ewe in late pregnancy. The quantities of hay consumed and the concentrate necessary for satisfactory ewe and lamb performance may be obtained by the adviser by referring to the data in Table 4.1. It must be stressed, however, that the data obtained on intakes of hay and concentrates were measured when a cereal based concentrate containing approximately 14% CP was used. Any major deviation from such a mix may have some effect upon forage intake. If the late pregnancy ration was to comprise turnips and hay or concentrates and silage then information from further trials similar to those described will be necessary. Advisory leaflets must make this clear.

The above data have also indicated that the ewe may be permitted to draw to a limited extent upon body reserves during late pregnancy. In practice a twin-bearing ewe may gain approximately 10% in gross body weight from eight weeks before lambing until just before parturition, which will result in a ewe body weight loss of approximately 7% from mid-pregnancy to 24 hours post partum. The body reserves act as a buffer to under-nourishment. Individual flock masters must decide upon a balance between body reserves depletion and the quantity of nutrient obtained from hay or concentrate to produce lambs. These data provide information to the farmer for objectively deciding upon the possible effects on output of the changes in body reserves that will result from the feeding of a given hay and a level of concentrate.

Relative costs of hay and concentrates and the monetary output will be the ultimate arbitrators of the quantities of feed offered during the expensive winter feeding period. It may be postulated that under the circumstances of more expensive hay and concentrate the greater accumulation of body reserves during periods of cheap feeding at grass and even greater subsequent reductions in body reserves in the late pregnancy period may be desirable on some farms. The decision will rest with the individual farmer. However, further data upon the interactions of body condition at the various stages of the ewe's year upon intake of forages, conception, and pre- and post-natal lamb growth are necessary before the agricultural adviser will have sufficient basis for the tailoring of advice to a given situation.

All the data were obtained using Scottish Halfbred ewes and are therefore limiting. Similar work carried out at other centres on different breeds or crosses may be necessary to take into account variations between breeds, size, feeding systems and management. Only in this manner will it be possible to provide sufficient information to cover all eventualities.

Re-emphasis of when the available concentrate should be supplied may be necessary, for it has been shown that the level of feeding during lactation has the greatest effect upon milk yield and lamb performance (see page 55). The Meat and Livestock Commission (Kilkenny personal communication) has found that for lowland ewes concentrates offered post parturition amount to approximately 11 kg out of a total of 55 kg supplied during late pregnancy and early lactation. It is suggested that with hays of average quality or better, the supplying of 15 kg of concentrate prior to lambing, and the feeding of one kilogram or more of concentrate per day, if necessary, until up to three weeks after lambing, when lactation is peaking (Wallace 1948a; Munro 1962; Peart 1971) would make better use of the available feed. Lambs would therefore have the greatest possible quantity of milk in early life. Such recommendations are in agreement with those of Large *et al* (1959).

Animals receiving conventional concentrate at any stage of the reproductive and production cycles are utilising food that may go more directly for human consumption. It is possible that as world population rises food will become scarcer and the processing of grains through ruminants may become even more uneconomic or politically hazardous. Circumstances will then dictate the utilization of forages alone by ruminants, and necessitate changes in systems of animal management which will permit the production of meat from all-forage diets. Lambing of ewes after, instead of prior to the commencement of the growth of grass in the spring will be necessary, and the appraisal of forage quality and its potential as a feed for pregnant ewes will then become of greater importance.

Further investigations into the feasibility of animal production systems based upon forages only are required to determine the quantities of feeds of different feed value necessary at the various stages of the productive cycle. The findings presented above provide a basis of evaluation for forage potential to provide for satisfactory ewe and lamb performance, and thus make large savings of concentrate input.

# APPENDIX

Table I

Hay quality in Britain

| No. of samples | Starch equivalent | Range | Crude protein % | Range or SD |
|---|---|---|---|---|
| 415 | 36.6 | 25.0-43.8 | 8.9 | 5.5-21.1 |
| 503 | 37.0 | 23.5-38.1 | 9.9 | 5.0-18.0 |
| 68 | 36.2 | 32.0-41.0 | 8.7 | 6.1-13.2 |
| | | Hampton (personal communication) | | |
| 47 | 36.9 | 17.0-56.0 | 9.6 | 6.3-16.7 |
| | | | Alderman *et al* (1966) | |
| 250 | 34.0 | - | 8.8 | - |
| 202 | 36.0 | - | 9.1 | - |
| 230 | 37.0 | - | 8.8 | - |
| 83 | 36.0 | - | 8.2 | - |
| 99 | 31.5 | 17.0-52.7 | 8.5 | 4.3-14.3 |
| | | | | Edwards (1973b) |
| 35 | 34.53 | - | 6.96 | ±1.73 |
| | Thompson, Gelman, Warren and Petchey (1972) | | | |
| 10,496 | 36.0 | - | 9.9* | - |
| | Agricultural Development and Advisory Service (personal communication) | | | |

*13,578

Table IIA

Range of % starch equivalent of hays

| Year | No. | <27 | 27-34 | 35-40 | 41-49 | 50-57 | >57 |
|---|---|---|---|---|---|---|---|
| 1970-71 | 5122 | 1.6 | 16.9 | 51.7 | 27.3 | 2.4 | 0.1 |
| 1971-72 | 3868 | 2.2 | 25.7 | 57.9 | 13.0 | 1.1 | 0.1 |
| 1972-73 | 163 | 10.4 | 35.0 | 42.9 | 11.7 | - | - |
| 1973-74 | 1343 | 1.7 | 25.2 | 47.3 | 22.7 | 2.8 | 0.3 |

Agricultural Development and Advisory Service (personal communication)

Table IIB

Range of % starch equivalent of hays

| Year | No. | <34.9 | 35.0-37.4 | 37.5-39.9 | 40.0-42.4 | 42.5-44.9 | 45.0-47.4 | 47.5-49.9 | >50.0 |
|---|---|---|---|---|---|---|---|---|---|
| 1971-72 | 406 | 1.2 | 2.0 | 3.4 | 12.3 | 30.8 | 37.7 | 9.6 | 3.0 |
| 1970-71 | 475 | 9.1 | 12.8 | 23.2 | 19.4 | 14.1 | 11.6 | 6.9 | 2.9 |
| 1969-70 | 311 | 9.0 | 9.6 | 22.2 | 26.7 | 19.6 | 7.1 | 2.9 | 2.9 |
| 1968-69 | 339 | 1.2 | 3.5 | 10.9 | 31.9 | 28.3 | 12.1 | 8.6 | 3.5 |
| 1967-68 | 232 | 8.2 | 11.2 | 18.1 | 21.1 | 22.0 | 10.8 | 3.4 | 5.2 |
| 1966-67 | 241 | 0.8 | 2.5 | 10.4 | 30.7 | 31.5 | 20.7 | 2.5 | 0.8 |

Alexander and McGowan
(unpublished data, personal communication)

Table IIIA

Range of % crude protein of hays

| Year | No. | <9.0 | 9.0-10.9 | 11.0-12.9 | 13.0-14.9 | 15.0-16.9 | >16.9 |
|---|---|---|---|---|---|---|---|
| 1970-71 | 5999 | 32.4 | 31.9 | 21.2 | 9.4 | 3.2 | 2.0 |
| 1971-72 | 4816 | 46.7 | 30.4 | 13.4 | 6.1 | 2.1 | 1.3 |
| 1972-73 | 1409 | 52.7 | 26.5 | 12.1 | 4.5 | 2.7 | 1.5 |
| 1973-74 | 1354 | 33.7 | 29.7 | 20.9 | 9.0 | 3.8 | 3.0 |

Agricultural Development and Advisory Service (personal communication)

Table IIIB

Range of % crude protein of hays

| Year | No. | 5.0 | 5.0-5.9 | 6.0-6.9 | 7.0-7.9 | 8.0-9.9 | 10.0-11.9 | 12.0-13.9 | 14.0-15.9 | 16.0-17.9 | 18.0-19.9 | 20.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1971-72 | 406 | 0.7 | 4.4 | 14.0 | 21.9 | 35.7 | 15.8 | 5.2 | 1.7 | 0.2 | - | 0.2 |
| 1970-71 | 475 | 1.1 | 1.5 | 5.9 | 14.1 | 41.0 | 21.3 | 7.6 | 4.8 | 0.8 | 1.3 | 0.6 |
| 1969-70 | 311 | 1.0 | 5.1 | 14.1 | 18.6 | 32.5 | 18.0 | 5.1 | 3.2 | 1.9 | - | 0.3 |
| 1968-69 | 339 | 0.9 | 5.3 | 14.2 | 19.2 | 29.8 | 22.4 | 6.2 | 1.8 | 0.3 | - | - |
| 1967-68 | 232 | 1.7 | 6.5 | 12.9 | 22.4 | 36.6 | 12.5 | 3.4 | 3.0 | 0.9 | - | - |
| 1966-67 | 241 | 0.8 | 5.0 | 8.7 | 16.6 | 45.6 | 17.8 | 3.3 | 1.7 | - | - | 0.4 |

Alexander and McGowan
(unpublished data, personal communication)

# Appendix I

## Hay quality in Britain

### (i) Introduction

An extensive survey of hay quality throughout the British Isles was carried out by contacting various organisations which routinely analyse large numbers of forage samples. Starch equivalent (SE) and crude protein (CP) in the dry matter were common to all reports. The data for SE and CP are presented as received in tabular form. Totals of 12,428 and 15,510 samples provided estimates of SE and CP respectively.

### (ii) Results

Table I summarises the data, and Tables IIA and IIB, and IIIA and IIIB indicate more accurately the distribution of hay quality as measured by SE and CP respectively. Excluding the data of Alexander and McGowan (personal communication) (see Tables IIB and IIIB) the mean SE was approximately 36 and the mean CP between 8 and 9%. The data from the Agricultural Development and Advisory Service (personal communication) indicated that approximately 70% of hays had SE values in excess of 35, and the corresponding data from Alexander and McGowan suggests that 70% of samples, analysed by them, had SE values above 40.

### (iii) Discussion and conclusions

The data were largely obtained from samples submitted for analysis by individual farmers. As a result the figures may be biased - the "better farmers submitting samples for analysis" (Alexander personal communication). This may account for the discrepancy between the data of Alexander and McGowan and those of the Agricultural Development and Advisory Service, whose data are in agreement with that of Rutledge and Common (1948).

Both Thompson, Gelman, Warren and Petchy (1972) and Morgan (1973), when discussing forage quality for dairy cows, considered that energy, rather than protein, was the most limiting constituent of hay, and Alexander (personal communication) believes that for practical purposes provided energy content of hay is adequate the protein level will be acceptable. Morgan (1973) stated that 35 to 75% (depending upon year and region) of hays had estimated metabolizable energy values of less than 8.3 MJ per kg DM (SE of 35). The implications are discussed above when considering ewe nutrition, forage quality, and the quantity of concentrate required with hays of a given quality.

# Appendix II

## Introduction

The above studies were designed to test the nutrient value of a range of hays as feeds for ewes in late pregnancy, and as part of a hay's evaluation included a component to measure lamb mortality and to determine causes of mortality. To provide sufficient animals on each diet to permit statistical analysis of the data many more animals per treatment would be necessary. Ewe health and lamb mortality are summarized below.

### (i) Ewes

Experiments 1.1 to 2.3

Hay 1) One ewe carrying quadruplets, and offered hay alone, prolapsed and aborted approximately four weeks prior to projected lambing date. All ewes being offered the forage alone for the determination of forage digestibility contracted pregnancy toxaemia on being transferred to metabolism cages. The four ewes aborted and one ewe later died.

3) Inappetance occurred with one ewe on the hay alone diet. No other symptoms were apparent. The diet was changed to hay 4) and the ewe lambed successfully at term.

6) Pregnancy toxaemia occurred in one ewe receiving a total of 30 kg of concentrate. Inappetance was noted four weeks prior to the clinical stages of the condition appearing at two weeks before lambing. Change of diet failed to encourage eating, and the ewe died one week after first exhibiting clinical symptoms.

7) Two ewes on the hay alone diet, each carrying triplets, exhibited inappetance four weeks prior to parturition. Pregnancy toxaemia occurred in both ewes. Diets were changed, and after medication one ewe aborted, and the other lambed at term. The ewe which aborted later died in an emaciated condition (score 0.5).

8) For no apparent reason one ewe on the diet providing 20 kg of concentrate aborted three lambs approximately ten days before projected lambing date.

Complete Ruminant Diet

Short periods of inappetance were noted in individuals. In trial 1.3, one ewe carrying triplets went off the feed three weeks prior to parturition. Symptoms typical of calcium deficiency were apparent, but after successful treatment the ewe refused to eat complete ruminant diet. A change of diet resulted in a normal lambing.

Experiments 3.1 and 3.2

3.1 No ewe mortality was observed before parturition, but two ewes died within three weeks of lambing. Ewes were very thin (score 0.5). Six ewes aborted, three of which are thought to have been caused by crushing and/or fighting. The remaining three each produced at least one rotten lamb, but no causal organism was isolated from the foetuses.

3.2 Prior to parturition there was no ewe mortality, but two ewes died from acidosis shortly after parturition. Both ewes had been on a concentrate free diet. Two ewes aborted, each one having one rotten and two normal lambs.

(ii) Lamb mortality

Lambs dying after parturition without apparent cause, were subjected to post mortem examination by the Veterinary Investigation Officers at The East of Scotland College of Agriculture, or the staff of the Royal (Dick) School of Veterinary Studies, Field Station, Easter Bush. Many of the reports were inconclusive, especially where starvation and/or colibacillosis (watery mouth) were observed together. In these cases it was not possible to determine the primary cause of death.

Of the 555 lambs born on all investigations in 1972, 6.8% were born dead or died during parturition, and 1.4% died through accident (drowning in water trough, lain on, etc); 1.0% were born deformed; another 9.0% died of causes attributable to starvation and/or colibacillosis, coli-septicaemia being apparent in some of the carcasses examined; 0.3% died from unknown causes.

In 1973 a total of 509 lambs were born to ewes on all experiments. 2.75% were born dead or died during parturition, 1.0% met with accidents and 0.2% were deformed. Colibacillosis and/or starvation accounted for 1.4% of lambs born, and 2.75% died of coli-septicaemia. Unknown causes accounted for 0.8% of lambs born.

A total of 116 lambs were produced by ewes on experiment in 1974. 9.5% of the lambs were born dead or died during parturition, and 6.9% died through agalactia which resulted in starvation and/or colibacillosis and coli-septicaemia. Two lambs (1.7%) died through accident.

Perinatal lamb mortality in 1972 and 1974 was higher at 18.5% and 18.0% respectively, than in 1973 when perinatal mortality was 9.0% According to Barton (personal communication) perinatal lamb mortality in the east of Scotland during the three years in comparable commercial flocks was from 5 to 50% with a mean of 15-20%. It may be suggested that there is great scope for a reduction in the mortality figures, but reference to the pooled breakdown of causes of death for the three years:

| | | |
|---|---|---|
| Total lambs born | 1180 | 100% |
| Total lambs dying | 170 | 14.4% |
| Total lambs born dead | 63 | 5.3% |
| Total lambs deformed | 7 | 0.6% |
| Total lambs dying by accident | 15 | 1.2% |
| Starvation/colibacillosis/septicaemia | 79 | 6.7% |
| Other causes | 6 | 0.5% |

would suggest that approximately 40% of deaths occurring would be unavoidable. Accident, and the complex of starvation/colibacillosis/septicaemia are the categories where there is most scope for improvement.

Lamb mortality has been widely surveyed, and has been considered in relation to nutrition (Wallace 1948a; Booth 1972; Thurley 1972), exposure (Booth 1972; Bastiman 1972b; Bastiman and Williams 1973), litter size (Purser and Young 1964; McDonald 1969), breed (Wiener, Deeble, Broadbent and Talbot 1973) and disease (Stamp 1967; Hughes, Haughey and Hartley 1971; Thurley 1972). The authors concur that mortality varies markedly in quantity and cause from flock to flock and is of the order of 15% of all lambs produced, the main cause of death being starvation (Stamp 1967; Booth 1972). According to Watson (1972), between 13 and 17 million lambs per year die in Australia before weaning, just under 7 million dying before suckling. Further work on methods of ensuring adequate milk supply at lambing and the ingestion of that milk by the young lamb as soon as possible after birth would be beneficial.

Appendix III

Below is a sample copied from the computer "print-out" of analysis of variance and table of means.

ANALYSIS OF VARIANCE

Ewe weight at 24 hours post parturition

| Source of variation | DF | SS | SS% | MS | VR |
|---|---|---|---|---|---|
| Units stratum | | | | | |
| Treat | 8 | 571.66 | 22.87 | 71.46 | 1.631 |
| Residual | 44 | 1927.92 | 77.13 | 43.82 | |
| Total | 52 | 2499.57 | 100.00 | 48.07 | |
| Grant total | 52 | 2499.57 | 100.00 | | |

Grand mean 75.63

Total number of observations 53

TABLES OF MEANS

Ewe weight at 24 hours post parturition

Grand mean 75.63

| Treat | 03-30 | 03-20 | 03-10 | 03-00 | 04-30 | 04-20 | 04-10 | 04-00 | 99-00* |
|---|---|---|---|---|---|---|---|---|---|
| | 76.67 | 76.17 | 72.33 | 70.50 | 77.83 | 77.42 | 73.67 | 73.08 | 82.17 |
| Rep | 6 | 6 | 6 | 5 | 6 | 6 | 6 | 6 | 6 |

Rep Unequal

SED 4.186X min rep
4.008 max-min
3.822 max rep

(no comparisons in categories where SED marked with an X)

Stratum standard errors and coefficients of variation

| Stratum | DF | SE | CV% |
|---|---|---|---|
| Units | 44 | 6.619 | 8.8 |

*99-00 = CRD

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