THE EFFECTS OF METHOD OF PRE-LAMB SHEARING OF EWES ON PRODUCTION AND PHYSIOLOGICAL INDICATORS OF COLD STRESS

A thesis presented in partial fulfillment
of the requirements for the degree
of Master of Agricultural Science
in Animal Science
at
Massey University

Kurnia Asumatrani Kamil

1990

ABSTRACT

This experiment was undertaken to compare the effects of two methods of pre-lamb shearing on physiological and production characteristics of ewes and their lambs with the objective of determining which method gives the greater advantages.

In July, approximately 20-63 days before lambing, sixty Romney ewes were divided at random into two equal groups, one group was shorn with a conventional comb and the other using a cover comb. The former left wool 1-3 mm in length and the latter 6-13 mm of wool on the animal after shearing. The ewes were run together on a rye grass white clover pasture for a 67 day period after shearing. Climatic conditions were considered mild with average minimum temperature of 5.2 ^{o}C, and average maximum temperature of 13.4 ^{o}C, average wind speeds of 8.5 km/h, relative humidity 80.1 %, sunshine 4.7 h and 1.2 mm of rainfall over the 67 days period after shearing.

Food intake, measured indirectly using controlled-release capsules containing chromium sesquioxide placed in the rumen, did not differ between the groups over a 21 day period after shearing. This was reflected in a lack of effect of treatment on the live weight of the ewes, birth weight of the lambs, growth rates of the lambs or wool growth of the ewes over the 67 day period. Ewes shorn by the conventional comb, however, were more severely stressed than the ewes shorn with the cover comb as indicated by the higher concentrations of non-esterified fatty acid (NEFA) and 3-hydroxybutyrate in the plasma of the former group on days 1 and 3 after shearing. Rectal temperature was a less sensitive measure than the concentrations of the metabolites and the difference between the groups in rectal temperature after shearing was not statistically significant. It was concluded that shearing with a cover comb reduces the cold stress on the ewe in comparison with the conventional method of shearing. Furthermore, it was suggested that under more severe climatic conditions than those experienced in the present experiment, that shearing with the cover comb might be expected to result in increased production.

ACKNOWLEDGEMENTS

Bismillahirrakhmanirrahim,
In the Name of Allah (God), the Compassionate, the Merciful, Praise be to Allah, Lord of the universe.

The first of all, I thank Allah (God) for His guidance and mercy to me.

My sincere thanks go to my teachers Professors D.D.S. Mackenzie, C.W. Holmes, R.D. Anderson; Drs I.M. Brookes, W.J. Parker for their valuable guidance, assistance, advice and encouragement throughout my studies. I am indebted particularly to my supervisor Professor D.D.S. Mackenzie who has guided me in writing up my thesis.

I would like to thank Mr K. Kilmister for taking care of the sheep during my experiment; the chief instructor of New Zealand Wool Board for shearing of the sheep; Mr D.L. Burnham, Mr G.S. Purchas, Miss Y.H. Cottam, Ms C.M.C. Jenkinson, Ms F.S. Jackson and Mr Z. Xu for their help in shearing, midside patch, measuring of rectal temperature, collecting faecal and blood samples; Ms F.S. Jackson and Miss M.F. Scott for metabolite analysis; Mr D.A. Hamilton for pasture analysis; Mrs Barbara Purchas and Mrs Kathy Morton for chromium analysis and also to those people who have helped me directly or indirectly.

I ackowledge also the valuable assistance from Mr J. Djegho and Mr M. Chozin.

I would also like to thank the New Zealand government for the scholarship that allowed me to carry out my studies and the Indonesian government for allowing me to study in New Zealand.

I would like to extend a very special thanks to my late parents who reared, guided and educated me. I will never forget their kindness.

Lastly, but the most important to my dear wife Euis Maryamah for her love, patience, comprehension, support and encouragement and also my fervent thanks to my children Ramdhan, Eka and M. Fauzie who were the main source of my inspiration.

TABLE OF CONTENTS

LIST OF TABLES

Table

LIST OF FIGURES

Figure

LIST OF ABBREVIATIONS

CRC = controlled-release capsules
d = day
DM = dry matter
DOMD = organic matter in dry matter
g = gram
h = hour
GLM = general linear model
ha = hectare
kg = kilo gram
km = kilo meter
mg = milli gram
NEFA = non-esterified fatty acid
l = litre
m = mile
ml = millilitre
mm = millimeter
mmol = millimol
ng = nano gram
OM = organic matter
OMD = organic matter digestibility
P = probability
r = correlation
RH = relative humidity
rpm = rotation per minute
s = second
SE = standard error
µeq = microequivalent

Level of statistical significance

NS = P>0.10 (not significant)
+ = 0.10>P>0.05
* = 0.05>P>0.01
** = 0.01>P>0.001
*** = 0.001>P

INTRODUCTION

I. INTRODUCTION

Sheep production in a grazing system is affected by the genetic make up of the animals and environmental factors (feed, climate and management). The improvement of environment can have a great impact on sheep production, therefore the objective of management practices should be to get most benefit for the farmer.

Shearing, to harvest the wool, is an important practice which can be managed in different ways. Two methods of pre-lamb shearing, conventional and cover methods were introduced in New Zealand many years ago, but little information is available on the comparative effects of these methods on sheep production and physiological responses (Bowen, 1963; Wodzicka-Tomaszewska, 1963; Thomsen, 1971).

Sheep exposed to cold conditions will lose heat to the environment, particularly recently shorn sheep and therefore they need more energy to cope with the cold stress. Information collected from over the world both in the field and under housed systems of management have shown that pre-lamb shearing increases feed intake. Lamb birth weight increased following pre-lamb shearing, perhaps caused by the increased feed intake which was reflected in the faster growth rates of the lambs (Austin and Young, 1977; Symonds *et al.* 1986). Sheep can maintain their deep body temperature relatively constant, however, eventually under extremes of environmental temperature rectal temperature may change. Rectal temperature of sheep exposed to cold stress tended to be lower (Bligh,

1973 and Stainer *et al.* 1984). Pre-lamb shearing increased the concentrations of non-esterified fatty acid (NEFA) and 3-hydroxybutyrate in blood plasma. These plasma metabolites have important roles in supplying energy during cold conditions (Thompson *et al.* 1982; Symonds *et al.* 1985; 1986; Astrup and Nedkvitne, 1988). Pre-lamb shearing also stimulated wool growth as measured by midside-patch wool production (Bigham, 1974).

However, these results were obtained under various conditions in different experiments and investigations into the effect of methods of pre-lamb shearing on feed intake, rectal temperature, lamb birth weight, metabolic effects and wool growth have not been done simultaneously in one experiment. Therefore, the present experiment was undertaken to compare the effects of the methods of pre-lamb shearing on physiological and production characteristics with the objective of determining which method gives the greatest advantages to the farmer in New Zealand.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

2.1. Shearing

The practice of shearing sheep to harvest their wool stretches back into prehistoric times. It is probable that initially the timing of shearing was haphazard but gradually a need for a fleece of useable staple length and the adoption of a yearly farming calender would have seen certain periods of the year being set aside for shearing. More recently the timing of shearing has been influenced by more specific farming objectives. Thus four times of shearing are common in New Zealand (Gaṇdar,1965). These are pre-lamb, immediately post-lambing, mid-lactation and post-weaning. All these have advantages and disadvantages with strong differences in opinion among the farmers about the correct time to shear pregnant or lactating ewes (Livingston and Parker, 1985). In this report only pre-lamb shearing will be discussed.

2.1.1. Pre-lamb shearing

The exact time when pre-lamb shearing was introduced in New Zealand is unknown. Some authors suggest it may have been introduced in the 1950's (Wodzicka-Tomaszewska, 1963). Certainly, since that time, particularly in the South Island, it has been more common for the

farmers to shear the pregnant ewes in August, a few weeks (4-6 weeks) before lambing commences (Story,1955; Gandar, 1965). This practice has considerable advantages from the point of view of sheep management and wool quality, while there are also some disadvantages. Many excellent references (Story, 1955; Bowen 1963; Wodzicka-Tomaszewska 1963; Henderson 1965; Livingston and Parker 1985) outline the advantages and disadvantages of pre-lamb shearing of ewes and these have been summarized as follows:

(1). Advantages

a. In bad weather during lambing shorn ewes seek shelter and thus tend to lose fewer lambs. There has been little formal evidence to substantiate this claim made by farmers.

b. Suckling is facilitated due to removal of wool around the udder of ewe, thereby increasing the chance of the lamb surviving. This is mimicked in partial shearing policies by crutching around the udder and rear end of the ewe prior to lambing.

c. During November-shearing (pre-wean), the lambs are necessarily separated from their mothers for a period. This may result in mis-mothering which may check their development. This problem is avoided by shearing before lambing or by delaying shearing until the lambs are weaned (December-January).

d. When ewes heavy in lamb are carrying a full fleece there is a greater tendency for them to be cast and be unable to get on their feet

again. It is therefore necessary to check them at least daily to detect any that are cast before they die. Parker (1984) found that the length of fleece was not strongly related to the incidence of casting, but this perception is held strongly by farmers. Pre-lamb shearing may reduce the incidence of casting and associated ewe losses.

e. Shearers are generally more available in July-August when they are mainly employed for crutching than in November, though this depends upon the number of farmers who wish to shear early.

f. Improved wool quality due to a lower incidence of cotting.

g. Improved wool quality because pre-lamb shearing reduces the proportion of wool fibres broken during processing. It is also less contaminated with plant material.

h. Improved lamb growth rates probably resulting indirectly from increased feed intake and milk production.

(2). Disadvantages

a. The ewes need more feed to cope with cold stress at a time when grass growth is low in winter. If feed availability is poor this will increase the incidence of pregnancy toxemia ('sleepy sickness').

b. It is normally more difficult to shear pregnant ewes, which must be handled more carefully. It is also harder to penetrate the wool of pregnant ewes with the blades or comb.

c. There is a considerable risk of ewes shorn before lambing dying from cold stress if there is a sudden change with very bad weather.

d. Shorn ewes are harder to catch at lambing if they require assistance due to lambing difficulties.

e. Weather conditions are usually wetter in the early spring and this makes it more difficult to have sheep dry prior to fleece removal. Delays in shearing, due to wet weather, may cause more sleepy sickness to occur if ewes are held on restricted areas near the shearing facilities.

2.1.2. Pre-lamb shearing methods

The history of sheep shearing methods in New Zealand has been reviewed by Bowen (1963) and Thomsen (1971).

In the nineteenth century sheep were shorn with blades (hand-shears) and even after the invention of a shearing machine by Austin Smith of Hawkes Bay in 1890 many farmers still preferred to have their sheep shorn with the blades. The reason for this preference was because a greater cover of wool was left on the sheep by the blade shearers and this protected the sheep from sudden cold snaps or storms which can come at almost any time of the year in New Zealand (Bowen, 1963). Nevertheless the machines required less skill and effort by the shearers and except in special areas have practically replaced the blades. Initially the narrow or conventional comb was used which leaves only 1-3 mm of wool on the sheep.

In 1913, Thomson Hokiaga of Porangahau, Hawkes Bay, introduced a new type of comb,the snow comb, from Australia which left 6-13 mm of wool on the sheep. This is equivalent to three weeks growth and is similar to that left by the blade shearers.

2.2. Body temperature

Sheep are homeothermic animals which means that they can maintain their deep body temperature even though the external temperature varies over a wide range. Body temperature is maintained constant by the metabolic activity of the tissues generating heat and mechanisms which regulate heat loss from the body. For further information refer to the reviews of Ingram and Mount (1975); Holmes (1979); Mount (1979) and Stainer *et al.* (1984).

Increased heat production of fed sheep after shearing have been observed by Farell and Corbett (1970); Davey (1973); Davey and Holmes (1977).

Sheep lose more heat in a cold environment, particularly after shearing. Farell and Corbett (1970), reported that fasting heat production in grazing sheep increased 44 % after shearing. Moreover, heat production increased 60-80 % in a group of shorn ewes compared with a group of unshorn ewes at 10 ^{o}C (Farell *et al.* 1972).

2.2.1. Heat production

Even though homeothermic animals are able to maintain their deep body temperature over a wide range of external temperature eventually under extreme conditions special action has to be taken either to generate extra heat to keep the body warm or to dissipate excess heat (Mount, 1979).

In cold conditions, the homeotherm as well as producing extra heat also increases overall thermal insulation by adopting a more compact body posture and by pilo erection and vasoconstriction. The combination of both heat production and thermal insulation enable the core temperature to be maintained. If conditions become too cold, the demand for heat production exceeds the animals metabolic capacity and body temperature begins to decline.

When the external temperature conditions become warmer or hot, the animal gains heat from the surroundings and then it dissipates heat and reduces insulation. This is achieved by adopting an extended posture with a raised skin temperature due to peripheral vasodilatation and an increased skin blood flow and by losing heat by evaporation either by sweating or by panting.

The upper and lower limits of environmental temperature for thermoregulation in the homeotherm are thus determined by the heat production capacity at low temperatures and by the heat dissipating

capacity at high temperatures. The range of environmental temperature in which the animal's metabolic rate is at a minimum, constant and independent of the environmental temperature is classically known as the zone of thermal neutrality. The lower and upper temperatures of that are called lower (LCT) and upper critical temperature (UCT). Below the LCT, the animal must increase the rate of heat production (HP) to maintain homeothermy, the rate of HP is dependent upon ambient thermal demand. Above UCT, body temperature may increase even though heat production decreases because evaporative heat loss is inadequate.

2.2.2. Factors affecting heat production

Under thermal neutral conditions heat is produced at a constant rate to maintain normal body function. The amount of heat produced is proportional to $W^{0.75}$ where W is the body weight, although in newborn lambs heat production may be directly proportional to body weight or according to some authorities the surface area of the lambs (Kleiber, 1961; Stainer *et al.* 1984).

The pattern of heat production varies over the day reflecting the diurnal pattern of activity characteristic of the sheep. Thus during the day metabolic activity associated with muscle movement and ingestion of food increases the amount of heat produced in comparison with that produced at night when the animal is resting (Stainer *et al.* 1984).

Cold conditions can be enhanced by increased wind velocity and by shearing. Graham *et al.* (1959) reported from calorimetric experiments that in still air at 10 ^{o}C the heat production of closely shorn sheep fed at approximately maintenance requirement increased by more than 50 %. Thus, Joyce and Blaxter (1964) reported that heat production by a sheep with a short fleece kept at -3 ^{o}C in a wind of 4.2 miles per hour was increased 3.3 times of that noted when it was in the thermoneutral zone. Moreover, Blaxter and Wainman (1964) showed that wind of 15 km/h increased heat loss by 2000 kcal/day, and rain by 1000 kcal/d, and cold, wind and rain together created heat losses 2-3 times greater than normal.

2.2.3. Heat loss

The maintenance of a relatively constant core temperature in animals exposed to fluctuating environmental temperatures is achieved by controlling heat loss either through non-evaporative or evaporative cooling.

2.2.3.1. Non-evaporative heat loss

Heat can be lost from the body by non evaporative mechanisms through radiation, convection and conduction. Such mechanism have

important roles particularly in cold conditions, in maintenance of body temperature.

(a). Conduction

Heat transfer by conduction is the exchange of heat from skin to the environment by direct contact. The amount of heat transfered will depend on the nature of the material in contact with the skin, in particular its thermal conductivity. Conductive heat transfer from the sheep generally plays a small role in the total heat transfer to the environment, but heat transfer by conduction through the tissues with in the body is important.

(b). Convection

This system involves the movement of a fluid or gas adjacent to the skin whose temperature changes as a result of conduction of heat from the skin to the fluid or gas. Therefore, it depends on the surface temperature of body, its shape, surface characteristics and size as well as the movement of the gas or fluid.

(c). Radiation

Heat transfer by radiation involves electromagnetic radiation of various wave lengths. Heat exchange by radiation in animals is considered in two parts. The first part deals with exchange when radiation from the surroundings is all 'long wave' that is, emitted by all surfaces whose temperatures is above 0 ^{o}K (-273 ^{o}C). The second part of radiant exchange includes the effects of shorter wavelength that is, emitted only by objects at very high temperature and also short wavelength can be reflected by surfaces.

2.2.3.2. Evaporative heat loss

This mechanism has an important role in dissipating heat to the surroundings in hot conditions because in these circumstances when the temperature gradient between body and environment is small, the rate of heat transfer by non evaporative pathway is very slow. The process occurs on the skin surface or in the respiratory tract.

(a). Skin

Heat is dissipated by the evaporative cooling of water secreted from the sweat glands. Therefore, the number and activity of the sweat

glands will influence the heat loss from the body of the animal. The number of sweat gland in sheep is about 240-340 per cm square.

(b). Respiratory tract

Evaporative cooling also occurs in the respiratory tract. It is facilitated by a special respiratory movement called panting. This consists of shallow rapid respiratory movements that greatly increase the movement of air to and from the upper respiratory tract, leading to a corresponding increase in evaporative cooling.

2.2.4. Regulation of deep body temperature

The hottest parts of the homeotherm are the heart, the liver and in certain conditions the brown fat. These are the organs where a large part of the resting body heat is generated, while the temperature of other organs at rest depends largely on the flow of blood from moment to moment (Stainer *et al.* 1984).

Rectal temperature is widely used for both the clinical and experimental measurement of core temperature because it is easily and safely measured (Bligh, 1973). The rectal temperature of sheep varies between 38.5-41 ^{o}C. This body temperature will be influenced by

environmental temperature, exercise, stress (including the stress of handling for making the measurement), feed intake and time of day (Bligh, 1973 and Stainer *et al.* 1984). Even though, deep body temperature remains relatively constant, skin temperature can exhibit large variation. Therefore, Holmes (1979) suggests calculating the average body temperature of an animal from measurements of both deep body and skin temperature as follows :

$$Tav = 0.7\ Tr + 0.3\ Ts$$

where ;

Tav = average temperature of the body

Tr = deep body, rectal temperature

Ts = average skin temperature

Regulation of body temperature is very complex and involves the integration of the activity of a large number of organs throughout the body. The thermostat in the hypothalamus receives information from temperature sensors throughout the body and then evokes the appropriate response by peripheral tissues (Bligh, 1973; Holmes, 1979; and Stainer *et al.* 1984).

2.3. Feed Intake

Shearing affects the intake of feed. For instance, shearing when the temperature was 16-17 ^{o}C increased the feed requirement by 18 % for housed sheep and by 24 % for exposed sheep (Elvidge and Coop, 1974). It is known that variation in feed intake has many effects on the performance of sheep including energy balance (Symonds *et al.* 1986), lamb birth weight (Austin and Young, 1977; Symonds *et al.* 1986), lamb growth rate (Austin and Young, 1977; Sumner *et al.* 1982), ewe live weight (Sumner *et al.* 1982) and wool production (Hawker *et al.* 1982, 1984).

The level of feed intake and the nutritive value of the feed have important roles in achieving production performance by animals. Therefore, feed intake and its variation is one of the major factors determining level and efficiency of animal production from pasture (Bines, 1979; Hodgson, 1982; Chase 1985 and Leaver, 1985).

The control of feed intake has been studied widely under indoor feeding conditions. However principles can be applied for grazing animals with certain restrictions (Arnold, 1970). Moreover, feed intake by grazing animals will also be affected by many other factors by which indoor animals are not influenced.

Voluntary feed intake under indoor conditions is affected by two main factors. Firstly, factors which influence the animal's requirement

for nutrients and its ability to metabolize absorbed nutrients. Secondly, factors which influence the animal's ability to consume the feed, accommodate and digest it in the digestive tract (Baumgardt, 1970; Bines, 1971). In grazing animals the interrelationship between the metabolic, physical and behavioral factors determine the mechanism of feed intake (Hodgson, 1977 and Minson, 1982). Therefore in this section, physiological control of intake and factors affecting feed intake are considered to understand better the effect of pre-lamb shearing on intake and production.

2.3.1. Physiological control of intake

The regulation of feed intake in animals has been investigated over a long time and the many theories of feed intake regulation were recently reviewed by Baile and Della-Fera (1981) and Forbes (1986). These theories may be classified into two main groups. The single factor or classical theories and the multiple factor or modern theories.

2.3.1.1. Single factor theories

There are three major single factor theories.

(a). Glucostatic control.

In this theory glucose is regarded as part of the controlling system for feeding in monogastric animals. In 1953, Mayer suggested that blood glucose concentration in the animal controls feed intake. Then in 1953 the same author reported that blood glucose concentration increases after eating and then decreases before the next meal (Forbes, 1986). However, in the ruminant animal there is little evidence supporting the involvement of glucose in the regulation of feed intake (Baile and Della-Fera, 1981).

(b). Thermostatic control

The principle of thermostatic control theory is that feed intake is needed to produce heat and maintain body temperature of the animal. A consequence, is that in cold conditions, feed intake increases while in warm conditions it will decrease. Forbes (1986) reported that this theory was suggested by Brobeck in 1948.

(c). Lipostatic control

It is known that free fatty acid concentrations in plasma are useful predictors of the mobilization of body fat reserves (Aulie *et al.*

1971). It is suggested that an increase of plasma free fatty acids after fasting or a period without eating might act as a signal to induce feeding (Baile and Della-Fera, 1981).

As a general conclusion, single factor theories are not regarded as satisfactory and the support for several single factor theories indicate that regulation of feed intake is very complex and involves many factors.

2.3.1.2. Multiple factor theories

Single factor theories only concentrate on one variable, such as blood concentration of a metabolite, while the multiple factor theories incorporate many aspects of metabolism and digestion.

Such an approach has been taken by Forbes (1986) who considers that the energy balance of the animal has an important role in regulating feed intake. Thereby, the animal eats to meet nutrient requirements but sensory factors are involved where, the animal will select only highly palatable feed.

An alternative hypothesis has been proposed by Baile and Della-Fera (1981) in which the central nervous system (CNS) is the primary site responsible for the overall control of feed intake but certainly involves many peripheral factors too. The various signals involved in

the control of feeding behaviour are regulated and integrated by the hypothalamus (Della-Fera and Baile, 1984). Even though details of the mechanisms for receiving and compiling the information from the periphery and then generating the appropriate response from the hypothalamus are not understood (Baile and Della-Fera, 1981). Evidence that the hypothalamus has the key role in regulating feed intake is reviewed by Baile *et al.* (1967 a). They reported that lesions in the ventromedial areas of the hypothalamus in goat causes hyperphagia and subsequent rapid weight increases and lesions in the lateral and anterior hypothalamic area causes temporary aphagia (Baile *et al.* 1968).

2.3.2. Factors affecting intake

Feed intake has a central role in the performance of animals, however, intake depends on many factors which are discussed in the following sections.

2.3.2.1. Animal factors

(a). Ingestive behaviour

The animal in harvesting pasture may sense the pasture condition through the use of sight, taste, smell and touch to select the pasture eaten (Poppi *et al.* 1987).

The mechanism of grazing intake has been reviewed by Hodgson (1985) and Poppi *et al.* (1987) and can be expressed as follows :

$$I = IB \times RB \times GT$$

where :

I = pasture intake (g/d)

IB = the weight of pasture eaten per bite (g/bite)

RB = the rate of biting during grazing (bites/minute)

GT = the time spent grazing (minutes per day)

Intake per bite is the most sensitive of the grazing behaviour parameters to changing sward condition, and both intake per bite and rate of biting are influenced by pasture characteristics. Intake per bite declines with reduced availability of pasture. Thereby, daily pasture intake commonly mirrors changes in intake per bite. The grazing time rarely exceeds 12-13 h/d and intake is not often maintained through increasing grazing time (Rattray and Clark, 1984 and Rattray *et al.* 1987).

(b). Age

Intake is influenced by energy demand of the animal. Thus, voluntary feed intake increases progressively until 30-40 % of mature

body weight is achieved and after that remains steady or decreases slightly. However, when voluntary feed intake was expressed per unit BW $^{0.75}$, a steady decrease was shown after the maximum of about 35 % of mature body weight was reached, consequently the voluntary feed intake at maturity was about 50% of the maximum attained (Weston, 1982).

(c). Pregnancy and lactation

Pregnancy status affects feed intake. It was found that intake increases for ewes carrying single foetuses while for ewes carrying twins and triplets there was a slight decline with advancing pregnancy (Hadjipieris and Holmes, 1966). This is supported by Owen and Ingleton (1963) who reported that intake did not increase concurrently with the demands of the foetus during the later stages of pregnancy and even became depressed as parturition approached.

Lambing and ensuing lactation resulted in an immediate increase in feed intake (Owen and Ingleton, 1963; Hadjipieris and Holmes, 1966). Feed intake of lactating ewes was significantly higher than that of dry or pregnant ewes and higher in ewes suckling twins than singles (Arnold, 1970). Furthermore, Hadjipieris and Holmes (1966) noted that lactating ewes rearing twins ate 1.85 kg/day over 10 weeks of lactation of dried grass pellets whereas ewes rearing a single lamb ate 1.55 kg DOM per day, compared with dry ewes which ate only 1.14 kg/day.

2.3.2.2. Feed factors

The two major feed factors affecting intake in pasture fed animal is the availability and the quality of the pasture offered.

(a). Availability

In general the level of intake increases with the pasture allowance where pasture allowance is the amount of pasture available to the animal and is defined as the weight of herbage per animal per unit time (kg DM/ewe/day) (Rattray and Clark, 1984). Furthermore, intake reaches a maximum with pasture allowance 3-5 times the intake.

It is self evident that the amount eaten by an animal is a function of the amount offered but the relationship in a grazing system is complex in that the density (kg DM/ha) of the pasture and the height (cm) of the pasture will influence intake at any given allowance (kg DM/ewe/day). Thus the reduction of pasture mass from 4020 kg DM/ha to 3290 kg DM/ha decreased intake per bite by 28 % (Forbes and Hodgson, 1985).

Effect of the pasture mass has been investigated by Poppi *et al.* (1987) who showed pre-grazing pasture mass which ranged between 2,000 to 5,000 kg DM/ha did not have any effect either on lamb intake or growth

rate. However, with pre-grazing pasture mass between 1,100 to 1,445 kg kg DM/ha (90 % green material) intakes of the ewes were reduced (Rattray and Clark, 1984).

(b). Quality

(i). Dead material content

Grazing sheep prefer green leafy pasture and reject dead material (L'Huillier *et al.* 1984). Dead material has a very low digestibility (40 %) compared with green material (80 %) (Rattray and Clark, 1984). Moreover, Butler *et al.* (1987) noted that animal performance over late spring and summer may be influenced by the level of leaf mass and dead matter in pasture but not the level of green grass stem.

(ii). Proportion of legume

Legumes have an important effect on intake at low pasture allowances (Rattray *et al.* 1987). They are very palatable and with the aerial distribution of their leaves they are easily prehended especially at low allowance. The rate of passage of legumes through the digestive tract is fast. Legumes are more digestible and the digested nutrient

more efficiently utilized for gains than grasses (Rattray and Clark, 1984). For instance, at low pasture allowances lamb growth rate can be 150 to 200 g/d higher on clover dominant pasture (60-80 % clover) than rye grass dominant pasture (0-25 % clover). While ewes gained 50-100 g/d more on clover dominant pasture (60-80 % clover) compared with rye grass dominant white clover (25-30 % clover) when the same DM allowance of each pasture was offered.

(iii). Grass characteristics

Grass as a main source of feed for the grazing animal has specific characteristics in the distribution of plants, length of tiller and height which can influence selection, rate of intake or bite size (Hodgson, 1982). For instance, leaf was eaten in preference to stem (Minson, 1982). Also as pasture plants mature there was usually an increase in the proportion of fibre and a reduction in the protein and non structural carbohydrate of the cell contents (Thornton and Minson, 1973).

2.3.2.3. Climatic effects

The effect of the temperature on sheep has been investigated by Bhattacharya and Uwayjan (1975) who reported that feed intake of sheep

under cool condition (11-22 ^{o}C.) was higher than under hot conditions (27-32 ^{o}C). More particularly exposure to cold stress increases voluntary intake in lambs and sheep. Dry matter intake was greater in growing lambs exposed to 0 ^{o}C compared to 23 ^{o}C (Soderquist and Knox, 1967) and feed intake increased in mature sheep housed indoors as still air temperature fell (Webster *et al.* 1969).

Cold stress can be induced by shearing and the increase in appetite following shearing is dependent on the temperature, prevailing weather conditions and quality of available feed. In one experiment with pen fed sheep intake increased by 40-50 % after shearing in winter (Wodzicka-Tomaszewska, 1963), while in another an increase of up to 70 % in intake was observed after shearing at 7-10 ^{o}C (Sumner *et al.* 1983). Under grazing conditions, sheep subjected to cold (14-27 ^{o}C) following shearing increased feed intake significantly by 42-62 % (Wheeler *et al.* 1963 and Sumner *et al.* 1983). The effects of the various components of climate on voluntary feed intake have not been studied comprehensively (Weston, 1982). However, wind can decrease the cold tolerance of freshly shorn adult sheep. Sheep with 7 mm of fleece withstood -15 ^{o}C but when they were wet and exposed to a 7 m/s wind they withstood only 13 ^{o}C (NRC, 1981).

2.3.3. Feed intake measurement

Measurement of feed intake is important in any study on factors affecting feed intake and its control. Methods for measuring feed intake may be classified as direct or indirect.

2.3.3.1. Direct methods

Feed intake by ruminant animals in stalls or pens can be readily measured by weighing the initial amount of feed offered and subtracting the weight not eaten. However, the measurement of feed intake by grazing animals is more difficult and relies on indirect methods (Forbes, 1986; Geenty and Rattray, 1987).

2.3.3.2. Indirect methods

An indirect estimate of feed intake by grazing animals can be obtained by measuring faecal output and estimating the digestibility of the pasture eaten. This intake is calculated by the rearrangement of the formula for calculating digestibility.

$$D = (I-FO)/I \times 100$$

where ;

D = digestibility of pasture

I = feed intake

FO = faecal output

so that ;

$$I = (FO/1-D) \times 100$$

The accuracy of the measure of intake will be dependent upon how accurately faecal output and digestibility of the consumed herbage can be estimated.

Indirect methods commonly rely on the use of a marker to estimate faecal output (Kobt and Luckey, 1972, Meijs 1981). The animal is dosed regularly with a known amount of a marker substance which is not absorbed or broken down during its passage through the alimentary tract. If these conditions are met then all the marker will appear in the faeces. If it is further assumed that the marker is evenly distributed throughout the faeces then the concentration of the marker will be inversely related to the volume of faeces. Thus by determining the concentration of the marker in a subsample of the faeces an estimate of the total volume of faeces can be made.

(a). Faecal output

Faecal output can be measured by direct collection or by indirect methods. The former can be carried out by total collection of faeces in bags attached to the animal (Meijs, 1981). Unfortunately this system can be a source of error because the collection equipment is a burden and

inconvenient for the animal so faeces may be lost. A marker which is commonly used is chromium oxide (Cr_2O_3) (Raymond and Minson, 1955; Forbes, 1986; Geenty and Rattray, 1987). Chromium oxide is used widely as a marker because it is inert and non toxic and is not absorbed (Lee *et al.* 1986).

Daily faecal output from the grazing animal can be calculated as follows (Geenty and Rattray, 1987).

$$FO = (1{,}000\ X)/Y$$

where ;

FO = faecal output (g/d)

X = Cr_2O_3 administered (g/d)

Y = Cr_2O_3 in faeces (mg/g DM)

(1). Administration of Cr2O3

Chromium oxide may be administered as a drench or in capsules deposited in the rumen (Raymond and Minson, 1955). The capsule consisting either of a gelatin shell containing a standard weight of chromium or a device which slowly releases Cr_2O_3 from a matrix contained within a plastic barrel (Ellis and Rodden, 1987 and Laby *et al.* 1984).

Early studies in which the Cr_2O_3 was drenched once daily showed large variation in estimates of faecal output because mixing of the marker and food in the gastrointestinal tract was incomplete. Therefore to improve the mixing the Cr_2O_3 was given twice (Raymond and Minson, 1955) or more frequently each day (Pigden and Brisson, 1956).

More recently, the use of gelatin capsules has increased the uniformity of dispersion of the marker and reduced the observed diurnal variation in faecal chromium content. This has facilitated the estimation of faecal output in groups of grazing animals and has the potential for application in individual animals (Ellis and Rodden, 1987). The use of controlled-release capsule (CRC) containing Cr_2O_3 allows more uniform distribution of Cr_2O_3 in the faeces of sheep and the diurnal variation of Cr_2O_3 excretion observed with twice daily dosing is reduced by one third (Ellis *et al.* 1981; Parker *et al.* 1989). The remaining variability in Cr_2O_3 concentration is more closely associated with the pattern of feed intake and flow of digesta (Laby *et al.* 1984).

(2). Recovery of Cr2O3

The recovery of Cr_2O_3 following administration of gelatin capsules is better than that following drenching with Cr_2O_3 in a suspension (Raymond and Minson, 1955). This difference may be due to slight losses of Cr_2O_3 during drenching whereas all the Cr_2O_3 enters the rumen when given by capsules.

Cr_2O_3 concentration in the faeces can reach stable values 5-6 days after inserting the capsule into the rumen and was similar to the daily release of Cr_2O_3 (Harrison *et al.* 1981 and Laby *et al.* 1984) and Cr_2O_3 release is linear and uniform over the period 5 to 30 days after dosing (Ellis and Rodden, 1987).

Recovery of Cr_2O_3 for cattle range from 76 to 119 % with large variation within and between days (Carruthers and Bryant, 1983). Furthermore, Raymonds and Minson (1955), reported that the Cr_2O_3 content of faeces from treated dairy cows varied between morning and evening samplings by as much as 15 % with a low value at 10-12 am and a high content at 2-4 pm. In the field the recovery in sheep ranged from 70 % to 130 % and indoors between 85 to 120 % (Raymonds and Minson, 1955). More recently, Parker *et al.* (1989) reported that recoveries were generally within 90-110 % in sheep given CRC.

(b). Digestibility

Digestibility of feed eaten by the animal is affected by the age, types of plant and climatic conditions. The average digestibilities of grasses in temperate countries were higher (68.2 %) than in tropical countries (55.4 %) (Minson, 1982).

Digestibility of pasture can be measured by several methods, these include marker-ratio, faecal index, fistulated animals and <u>in vitro</u>

techniques (Roughan and Holland, 1977; Holmes, 1980; Meijs, 1981). However, the *in vitro* technique has the advantages of speed, cheapness and precision and is also applicable to forages at all stages of maturity.

2.4. Metabolic effects

New Zealand is a temperate country where there is a distinct seasonal variation in environmental temperature from cold in winter to warm or hot in summer. Coinciding with this, pregnancy and lambing commonly occur in the cold conditions of winter and early spring. In addition some farmers shear their sheep before lambing at the end of winter. Although little is known about the effects of pre-lambing shearing and exposure of the ewe to cold condition on the concentration of specific metabolites such as glucose, non esterified fatty acids (NEFA), 3 hydroxybutyrate (BHOB), urea and creatinine in the plasma, the concentrations of some of these metabolites vary in response to cold stress. The present experiments were undertaken to obtain further information on the effect of cold stress on the concentration of various plasma metabolites and to asses the severity of the stress imposed by different methods of shearing by measuring the changes in plasma concentration of various metabolites.

2.4.1. Glucose

Glucose is an important energy source for ruminants including the sheep. It is needed by a variety of tissues, especially the brain, in order to maintain normal function and consequently its concentration in plasma is maintained very constant by complex homeostatic mechanisms.

2.4.1.1. Glucose requirement

The activity of the whole body is controlled by the central nervous system with the hypothalamus as a main regulator. A constant supply of glucose is needed to maintain the activity of the nervous system including the brain of sheep. Furthermore, Linzell (1974) showed that about 30-50 % of the energy of the fed goat is gained from the oxidation of glucose.

Pregnancy and lactation increase the demand for energy especially glucose. In pregnant sheep, the utilization of glucose by the conceptus is large (Hay *et al.* 1983) and the rate of gluconeogenesis increases two fold in late pregnancy (Faulkner, 1983). During lactation in goats up to 85 % of the glucose available to the body is used by the mammary gland for milk synthesis for which it is an essential precursor (Davies and Bauman, 1974).

2.4.1.2. Glucose precursors

There are three sources of glucose in the ruminant animal. Firstly a little glucose can be gained from the digestive tract . Secondly, glycerol released from body fat reserves, amino acids from tissue protein and glycogen reserves, are potential sources of glucose. Thirdly, the major portion of glucose available to the ruminant is supplied by glucogenesis from products of digestion such as propionic acid and amino acids (Lindsay, 1970). Therefore, the provision of glucose is an energetically expensive process and the ruminant animal may be expected to have evolved a variety of mechanisms for conserving glucose carbon. These mechanisms play particularly important roles in situations where glucose demand is high, such as in late pregnancy and early lactation (Linzell, 1974).

The liver is the main source of glucose production (65-80 %) during both pregnany and lactation (Van der Walt *et al.* 1983). Other sources are the portal-drained viscera (absorbed glucose) and the kidneys.

2.4.1.3. Glucose utilization

In the non-lactating ruminant oxidation of glucose is an important source of energy for tissues such as the central nervous system. Oxidation of glucose via the pentose phosphate pathway provide a

proportion of the NADPH required for fat synthesis in the adipose tissue. Glucose is also an important precursor for the glycerol moiety of the triacyl glycerides formed in the adipose tissue. Glucose is an important precursor of oxaloacetate and hence plays a major role in the function of the tricarboxylic acid cycle. Over 80 % of the glucose is utilized by the peripheral tissues in the non pregnant, non lactating sheep with approximately 35-40 % of the utilization being attributable to the hind quarters (Van der Walt *et al.* 1983).

The glucose concentration in the blood of ruminant animals varies between 40-60 mg/100 ml (Schultz, 1974). This concentration is necessary to maintain the normal function of many body tissues. Lower blood glucose concentrations can lead to the development of ketosis while higher concentrations increase the rate of glucose utilization. Blood concentration can be influenced by many factors particularly pregnancy and lactation (Chaiyabutr *et al.* 1982 and Baird *et al.* 1983), cold stress due to shearing (Symonds *et al.* 1985, 1986), and plane of nutrition (Chandler *et al.* 1985; Metz and Van den Berg, 1977). Blood glucose concentrations, however are an unreliable indicator of the rate of glucose metabolism.

The rate of glucose utilization by the tissues can be estimated by measuring the entry rate of glucose into the circulation using isotope dilution techniques. The entry rate of glucose was 28 % higher in shorn ewes compared with unshorn, even though there was no difference in the arterial plasma concentration of glucose (McKay *et al.* 1974). Furthermore, studies in fed non pregnant ewes after shearing showed that

glucose entry rate was increased from 2.07 gC/d per kg live weight $^{0.75}$ when measured at 18 ^{o}C to 5.07 gC/d per kg live weight $^{0.75}$ after being maintained at an environmental temperature of -2 ^{o}C for 6 weeks.

2.4.1.4. Factors affecting glucose metabolism

As outlined glucose concentration and metabolism can be influenced by many factors.

(a). Pregnancy and lactation

Pregnant sheep have a higher rate of glucose production because the utilization rate of glucose by the conceptus is large (Hay *et al.* 1983) and glucose concentration in ewes is affected by pregnancy and the level of nutrient intake (Davies *et al.* 1971). Thus glucose synthesis and utilization increased during pregnancy and lactation in fed but not in starved goats (Chaiyabutr *et al.* 1982). In ewes, circulating concentration of glucose tend to be higher during lactation than during pregnancy (Baird *et al.* 1983). In the lactating animal more than 50 % of this glucose was removed by the mammary glands (Chaiyabutr *et al.* 1982).

(b). Nutrition

Undernutrition caused significant decreases in maternal and foetal blood glucose concentrations which were accompanied by 46-63 % decreases in the uptake of glucose by the various tissues of the uterus and conceptus (Chandler *et al.* 1985). Starvation decreases the rate of glucose synthesis and increases the dependence of the tissues on lipid as an energy source (Bergman, 1973). The immediate effect of incomplete starvation was to lower plasma glucose concentration (Patterson, 1964).

Differences in glucose metabolism measurements between thin and fat sheep were greater on a high plane of feeding while the differences became less or disappeared during fasting (McNiven, 1984).

(c). Cold stress and shearing

In cold conditions, pregnancy increases the production of heat which could be used to maintain body temperature by about 40 % (Aulie *et al.* 1971). Moreover, Tsuda *et al.* (1984) reported that heat production of sheep exposed to 0 ^{o}C increased 2.14 times compared with those at 20 ^{o}C. At 0 ^{o}C the percentage of total heat production derived from oxidation of acetic acid decreased and the substances which contributed 50 % of the heat were not identified and remained unknown. However, they suggested it was produced from the oxidation of lactic acid, amino

acids and derivatives of butyric acid. In addition, the turnover rate of acetic acid, which is the main energy source for the ruminant, showed no difference between the two regimes but the turnover of glucose increased significantly at 0 ^{o}C. Therefore, glucose is one of the important energy sources when the animal lacks energy either due to cold condition or starvation (Patterson *et al.* 1964).

The glucose concentrations of shorn sheep exposed to cold (8 ^{o}C) was higher than that of sheep in hot conditions (30 ^{o}C) (Halliday *et al.* 1969) and pregnant sheep (Mellor *et al.* 1975; Thompson *et al.* 1982). The effects of both acute and chronic exposure to cold were studied by Thompson *et al.* (1982). Exposure to a cold environment for a period between 0.5 and 2 hour increased the concentration of glucose in maternal plasma. Furthermore, at the end of 2 hours in the cold, foetal plasma glucose concentration was also higher than control values in the neutral environment. Therefore, there was a positive correlation between maternal and foetal plasma glucose concentration in cold conditions (Thompson *et al.* 1982). Following a long term exposure to cold, there was also a significant increase in whole body glucose entry in the shorn pregnant ewe (Symonds *et al.* 1988).

Cold stress can be induced by shearing. Plasma glucose concentrations in pregnant ewes temporarily increased after shearing then fell shortly before lambing (Astrup and Nedkvitne, 1988). Symonds *et al.* (1985,1986) reported that plasma glucose concentration is increased in the pregnant ewe shorn three weeks before parturation. There are many factor associated with this. Glucose concentration may

have increased as a result of an increase in maternal glucose production or a decrease in glucose utilization or both. A decrease in utilization being due to increase in maternal fat oxidation, while an increase in production of glucose is perhaps more likely since long term cold exposure of non pregnant sheep results in higher oxidative requirements for glucose (McKay *et al.* 1974).

2.4.2. NEFA (Non esterified fatty acids)

In 1956, Dole found a positive correlation between the nutritional state of human subjects and plasma NEFA concentration (Annison, 1960). Since that time plasma concentration of NEFA have proven to be useful indicators of fat mobilization (Aulie *et al.* 1971). Thereby, changing levels of NEFA in plasma generally reflects changes in the rate of depot fat mobilization (Halliday *et al.* 1969).

2.4.2.1. NEFA requirements

NEFA are an important source of energy (Aulie *et al.* 1971 and Symonds *et al.* 1986), particularly in fasted sheep (Graham and Phillips, 1981). The energy demand in early lactation is high and often results in a negative energy balance. Cows mobilize their adipose tissue to support the shortage of energy and this is reflected in the increasing NEFA concentrations (Miettinen and Huhtanen, 1989).

2.4.2.2. NEFA precursors

Triglycerides (triacylglycerols) present in the adipose tissue are regarded as a potential source of energy when energy intake is insufficient to meet the demands of the animal. The triglycerides are hydrolysed by a hormone-sensitive lipase releasing glycerol and NEFA into the blood stream. The glycerol can be converted to glucose in the liver while the NEFA may undergo breakdown in a number of tissues by beta-oxidation to acetyl CoA which enters the tricarboxylic acid (TCA) cycle and is oxidized (Metz and Van den Berg, 1977). NEFA are also major precursors for ketone body formation in the ruminant animal and it was showed by Schultz (1974) that more than 40 % of the ketones in fed goats were derived from NEFA while in the fasted ketotic animal all of them come from NEFA. Finally NEFA may be resynthesised into triglycerides in the liver and released into the circulation as lipoproteins.

2.4.2.3. NEFA Metabolism

The concentration of NEFA in the plasma of non-pregnant sheep lies between 0.1 - 0.9 µequiv/l (Annison, 1960). Changes in the concentration of NEFA reflects changes in the deposition and mobilization of fat from the adipose tissue (Halliday *et al.* 1969 and Aulie *et al.* 1971).

2.4.2.4. Factors affecting NEFA metabolism

There are many factors affecting NEFA concentration in sheep. The most important factors are summerized as follows.

(a). Pregnancy

During the first two months of pregnancy NEFA concentrations were low and relatively constant (mean 0.43 µequiv/l) (Aulie *et al.* 1971) but increasing to relatively high concentrations (1-2.5 µequiv/l) late in lactation (Annison, 1960).

(b). Fasting and underfeeding condition

When non pregnant sheep were fasted, plasma NEFA steadily increased reaching a maximum after 3-5 days, while in pregnant sheep, fasting resulted in a rapid rise in plasma NEFA concentration with a 5-10 fold increase occurring within 24 hours (Annison, 1960). Furthermore, the plasma level of NEFA in starved sheep can be up to 6 times higher than those of fed sheep (Patterson, 1963). However, the immediate effect of incomplete starvation was to raise the plasma NEFA level and lower the plasma glucose level.

Chandler *et al.* (1985), reported that mean arterial plasma NEFA concentration was more than double in undernourished ewes compared with fed ewes. Exercise caused significant increases in arterial plasma NEFA concentration in both fed and underfed ewes.

(c). Cold stress and shearing

Plasma NEFA concentrations in sheep can be affected by cold conditions (Halliday *et al.* 1969;Stott and Slee, 1985). The acute exposure of pregnant sheep to cold increased concentration of NEFA in maternal plasma, however the concentration in foetal plasma decreased (Thompson *et al.* 1982). When shorn sheep with a fleece length of 5-10 mm were transferred from a thermoneutral temperature and exposed to -20 ^{o}C, plasma NEFA concentration increased to 3500 µequiv/l during the first day of exposure (Halliday *et al.* 1969). Moreover, Elvidge and Coop (1974) reported NEFA concentration in woolly sheep of around 300-600 µequiv/l while in shorn sheep the concentration were 500-1200 µequiv/l.

NEFA concentration were elevated on days 4 and 10 after shearing in pregnant ewes, but there were no significant differences between shorn and unshorn over the remaining seven weeks of pregnancy (Astrup and Nedkvitne, 1988 and Symonds *et al.* 1988a).

2.4.3. 3-hydroxybutyrate

3-hydroxybutyrate is one of the ketone bodies and it is an important alternative substrate to glucose for supplying energy (Williamson, 1981). It is produced from the butyrate absorbed from the rumen and by incomplete oxidation of NEFA.

2.4.3.1. 3-hydroxybutyrate requirements

3-hydroxybutyrate is an important precursor for the synthesis of fatty acids in the adipose tissue and also as a source of energy in muscle and mammary gland (Palmquist *et al.* 1969). Shaw and Knodt in 1941, demonstrated that 3-hydroxybutyrate contributed to milk fat synthesis, as indicated by the considerable uptake of this hydroxy acid by the lactating udder of the cow (Davis and Bauman, 1974). Subsequent studies have shown conclusively that 3-hydroxybutyrate is incorporated into milk fatty acid (Palmquist *et al.* 1969). Moreover, 8 % of the total fatty acid carbon was derived from this metabolite.

2.4.3.2. 3-hydroxybutyrate precursors

Up to 50 % of the 3-hydroxybutyrate is formed from butyric acid as it is absorbed by the rumen epithelium or in the liver (Williamson,

1981). The remainder is formed by incomplete oxidation of long chain fatty acids in the liver.

2.4.3.3. 3-hydroxybutyrate concentration

The concentration of 3-hydroxybutyrate in normal sheep were on average 0.62 mM (Williamson, 1981). However, it will vary depending on many factors.

2.4.3.4. Factors affecting 3-hydroxybutyrate concentration

(a). Cold stress and shearing

Symonds *et al.* (1986), found that shearing did not influence the plasma concentration of 3-hydroxybutyrate over a 24 h period 19 days before lambing. Furthermore, plasma 3-hydroxybutyrate concentrations in winter shorn ewes were similar to or even lower than unshorn controls particularly over the final 4 weeks of pregnancy, despite the increase energy requirements of the shorn animal (Symonds *et al.* 1988). In contrast, Russel *et al.* (1985) reported that plasma 3-hydroxybutyrate concentrations of shorn pregnant ewes were significantly higher than those of unshorn pregnant ewes when the environmental temperature ranged between 3-10 ^{o}C.

(b). Underfeeding

In resting, undernourished ewes, mean arterial plasma 3-hydroxybutyrate levels were increased almost 4 fold (Chandler *et al.* 1985).

2.4.4. Urea and creatinine concentration

Protein ingested by sheep is hydrolyzed in the rumen to amino acids and peptides and then deaminated with subsequent accumulation of ammonia. This is absorbed from the rumen into the portal blood vessel in which it is carried to the liver where it is converted to urea and subsequently excreted in the urine (McIntyre, 1970; Campbell, 1973; Marshall and Hughes, 1980). Similarly the deamination of amino acids in the body also leads to the production of urea principally in the liver. Creatinine is a complex nitrogen-containing substance derived from the breakdown of endogenous creatine phosphate in the body tissues (Marshall and Hughes, 1980). The amount produced is approximately proportional to the mass of muscle.

Factors affecting urea and creatinine metabolism

(a). Shearing

Plasma urea concentration generally increases as intake of feed increases (Thornton, 1970), however, urea concentration decreased significantly 8 days after shearing despite an increase in food intake after shearing (Astrup and Nedkvitne, 1988). No explanation was given for this decrease in urea concentration.

(b). Feed

Plasma urea increased with increased intake of feed due to nitrogen intake increasing (Goodwin and William, 1984). However, plasma urea increased due to the reduction in food intake during late pregnancy in the ewe (Guada *et al.* 1976).

Plasma urea concentration declined by about 25 % during fasting (52 h) while creatinine remained stable in Romney rams (McCutcheon *et al.* 1987).

2.5. Effects of pre-lamb shearing on animal production

There is only limited evidence, particularly for New Zealand farming conditions, supporting the hypothesis that pre-lamb shearing stimulates lamb birth weight, lamb growth, ewe weight and wool growth.

2.5.1. Lamb birth weight

There has been extensive research on the effects of pre-lamb shearing on lamb birth weight both in the field and under housed rearing systems. Overall the results of these indicate that lamb birth weight is increased following pre-lamb shearing even though the increase is not always significant (Nedkvitne, 1972; Austin and Young, 1977; Russel *et al.* 1985 and Symonds *et al.* 1986). Thus, under housed conditions birth weights of single lambs and twins were heavier for shorn than unshorn ewes (Austin and Young, 1977; Russel *et al.* 1985). Increased lamb birth weight from shorn ewes was associated with increased feed intake after shearing (Wodzicka-Tomaszewska, 1963; Austin and Young, 1977 and Maund, 1980). For instance, the shorn ewes consumed 14 % more hay than unshorn ewes (Austin and Young, 1977). Exposure of pregnant sheep to cold can alter the partitioning of nutrients between mother and foetus (Thompson *et al.* 1982) although the mechanisms are not understood. Moreover, increased lamb birth weight is not always due to increased feed intake. Thompson *et al.* (1982) reported a 15 % increase in lamb birth weight

when shorn ewes were maintained at 1-2 ^{o}C and food intake was kept similar to that of a control group housed in a thermoneutral environment (15 ^{o}C).

Under field condition winter shearing of pregnant ewes during the final 10 weeks of gestation increased birth weight of single lamb (Symonds *et al.* (1986) and also the mean lamb birth weight of twins or triplets (Maund, 1986).

It might be anticipated that because the lambs are bigger that pre-lamb shearing would reduce the lamb mortality. In one experiment the mortality of twin and triplet lambs was reduced (Nedkvitne, 1972), but in another there was no increase in lamb survival following shearing ewes 4-6 weeks before lambing (Sumner *et al.* 1982).

2.5.2. Lamb and ewe growth

It has been recognized that shearing stimulates voluntary feed intake of pregnant and non-pregnant sheep (Webster and Lynch, 1966; Ternouth and Beattie, 1970; Maund, 1980 and Russel *et al.* 1985). It therefore follows with the increase in feed intake after shearing that more protein and energy is available to the sheep. If energy available is greater than that needed to meet the requirement for increased heat production a proportion of the extra nutrient ingested may be available for short term increase in body growth or for additional milk

production. Shearing housed pregnant ewes at about the end of the first trimester of pregnancy resulted in increased ewe live weight gain (Austin and Young, 1977). Also, the lambs born to the shorn ewes grew faster than those born to the woolly ewes (Austin and Young, 1977 and Sumner *et al.* 1982).

2.5.3. Wool production

Wool is a valuable product for New Zealand sheep farmers contributing 30-70 % of total gross income. However, wool growth and production are influenced by many factors which determine the quality and quantity of wool, and eventually the income of the farmer. Factors affecting wool production are summarized below:

2.5.3.1. Pregnancy and lactation

It has been showed that pregnancy reduces clean wool growth in mid to late pregnancy and throughout lactation (Oddy, 1985). Furthermore, in general the largest depression in wool growth due to pregnancy and lactation occurs in those ewes which produce the greatest amount of wool.

Wool growth depression during pregnancy may be related to lamb birth weight and during lactation to milk production (Corbett and

Furnival, 1976). Ewes with a single lamb generally produce 10-20 % (0.3-0.5 kg greasy wool) less fleece wool than those that do not become pregnant (Williams *et al.* 1978). Moreover, the bearing of twin lambs reduces annual wool production by a further 0-10 % (0-0.5 kg greasy wool). During lactation the clean wool growth decreased as milk production increased and for every litre of milk produced there was a decrease of 12 g clean wool (Oddy, 1985).A reduction in clean fleece weight of about 5 % occurs at weaning after 5 months lactation compared with 6 weeks (Corbett and Furnival, 1976). Sumner *et al.*(1985) reported that fleece weight in New Zealand sheep is depressed by between 3 and 5 % for each additional lamb reared. Annual wool growth in Merino ewes is decreased from 7-26 % as a result of bearing and rearing lambs (Corbett, 1979) and the decrease is greatest in ewes rearing twins (Oddy, 1985).

2.5.3.2. Nutrition

The availability of feed affects wool production and it is associated with the season. Wool growth responses of New Zealand Romney ewes to increasing pasture allowance in the autumn, winter, spring and summer have been reported by Hawker *et al.* (1982, 1984). Wool growth increased curvilinearly with pasture allowance in each season with the response being greater in summer and autumn than in winter, with spring intermediate. It is known that wool grows up to 4 times faster in summer than in late winter-early spring and the minimum rate decreases and occurs later with an increasing number of lambs (Story and Ross, 1960;

Gandar, 1965). The sheep which were higher wool producers under grazing condition were also higher wool producers when fed in pens. They produced 25 % more clean scoured wool than the lower wool producers on restricted intake and 30 % more under ad libitum feeding condition (Wodzicka-Tomaszewska, 1963). Early weaning and good feeding of the ewe increased wool growth and mean fibre diameter (Smeaton *et al.* 1983).

During the final four weeks of pregnancy and the first six weeks of lactation supplementation with casein increased wool growth and fibre diameter (Williams *et al.* 1978). Furthermore, ewes supplemented with methionine and cystine produced wool with the greatest sulphur content. Wool sulphur content increased during pregnancy but not during lactation (Oddy, 1985). Casein and the sulphur containing amino acids, cysteine and methionine cause large and immediate increases in the rate of wool growth when infused directly into the abomasum of non-breeding sheep consuming roughage diets (Williams *et al.* 1978). The rate of wool production appears to be influenced largely by the quantity of amino acids, absorbed from the intestines, although the supply of energy can apparently modify the response (Black *et al.* 1973).

2.5.3.3. Shearing

Shearing stimulated wool growth and altered the annual wool growth cycle as measured by the midside patch technique (Bigham, 1974).

Wool production has a well defined annual cycle which is associated with a reduction in fibre diameter during the period of slowest growth (winter) . Pre-lamb shorn wool is sound because it is shorn near the time when fibre diameter is at a minimum and wool shorn at any other time has a thin region where it is likely to break (Story and Ross, 1960).Wool fibre diameter was reduced during the first month of lactation (Oddy, 1985).

The time and frequency of shearing have the greatest impact on subsequent manufacturing performance of the wool. Twice shorn Romney and Perendale ewes grew more greasy and clean wool than once shorn ewes (Gandar, 1965). Total clean wool production of twice shorn Romney ewes was greater than once shorn ewes with the effect being greater following second shearing in May and October (Sumner and Willoughby, 1985; Sumner and Armstrong, 1987). Wools shorn between May and October were less discoloured than wools shorn between November and February (Sumner and Armstrong, 1987). Furthermore, once shorn wools were more discoloured than twice shorn wools (Smith, 1980 and Sumner and Armstrong, 1987). Average net returns to the farmer were greater for once shorn ewes (Sumner and Willoughby, 1985 and Sumner and Armstrong, 1987). Thus the main disadvantage of double shearing is the reduced wool fibre length (Smith *et al*. 1980). The feeding level during mid-pregnancy produced significant differences in staple strength and diameter at the point of break (Fitzgerald and Smeaton, 1984).

2.5.3.4. Age and breed

Wool production increases with age reaching a maximum at 3-4 years of age before slowly declining (Sumner *et al.* 1985). In addition, breed can influence the wool growth. Sumner (1983) reported in hoggets that wool growth rate of the Cheviot was 40 % less than that of the Drysdale and Romney and was less influenced by feed allowance than the other two breeds. Furthermore, its fleece characteristic was both coarser and bulkier than Drysdale or Romney wool. However, Romney wool was yellower than the other two breeds.

MATERIALS AND METHODS

III. MATERIALS AND METHODS

3.1. Experimental animals

Sixty Romney ewes aged between 2 and 6 years and weighing 58.11 ± 0.88 kg at the beginning of experiment were used. The ewes were mated to two Romney rams between 10 March and 15 April 1989. The ewes were grazed on a mixed rye grass-white clover pasture at a stocking rate of 10 ewes/ha on the Sheep and Beef Cattle Research Unit, Massey University.

3.2. Experimental procedures

3.2.1. Shearing treatment

The ewes were shorn on 27 July 1989 (day 0) by the chief instructor of the New Zealand Wool Board shearing school. For shearing the ewes were divided at random into two equal groups, one group were shorn by the conventional method and the other using a cover comb. The former left wool 1-3 mm long and the latter 6-13 mm long on the animal after shearing.

3.2.2. Intake measurement

Feed intake was measured by an indirect method using controlled-release capsules (CRC) placed in the rumen which uniformly released chromium sesquioxide (Cr_2O_3). Three days prior to shearing (24 July; day -3) a single CRC was dosed to each of ten ewes selected at random from each of the shearing groups.

Collection of faecal samples commenced 7 days after capsule administration and was carried out on days 4, 5, 6, 11, 12, 13, 18, 19, and 20 after shearing. At each collection ewes were yarded and a sample of faeces was recovered from the rectum of each ewe. Faecal samples were dried in an oven at 110 ^{o}C for 24 hours in preparation for Cr_2O_3 analysis (3.3.3.4). The output of faecal dry matter was calculated from the relationship :

$$FO = X/Y$$

where ;

X = (Cr_2O_3) faeces (mgCr/gDM)

Y = (Cr_2O_3) released/day(mgCr)

Subsequently, feed intake was calculated from the relationship between faecal output, feed intake and digestibility of the feed.

$$FI = FO/(1-d)$$

where ;

FI = feed intake (kg/d)

FO = faecal output (kg/d)

d = digestibility of pasture (estimation outlined on 3.3.3.3)

3.2.3. Collection of blood samples

Blood samples from each ewe were collected between 0800 and 0900 h on each of the two days immediately before shearing (days -1 and -2) and on days 1, 3, 7 and 14 after shearing.

Blood samples (10 ml) were withdrawn by venipuncture from the jugular vein using heparinized vacutainers (Neo tube, Nipro Medical Industries, Tokyo, Japan). Plasma was separated by centrifugation at 3000 rpm for 20 minutes and stored at -20 ^{o}C until required for determination of plasma glucose, non esterified fatty acid (NEFA), 3-hydroxybutyrate, urea and creatinine.

3.2.4. Measurement of rectal temperature

Rectal temperatures of all the ewes were measured between 0730 and 0830 h on the two days immediately before shearing and on days 1, 3, 7 and 14 after shearing. Rectal temperatures were determined by inserting a Zeal clinical thermometer in to the rectum for at least 3 minutes.

3.2.5. Measurement of residual wool after shearing and wool growth

The amount of wool left on the animal by the different methods of shearing was measured by clipping all the residual wool from a midside patch (Bigham, 1974). A rectangular patch approximately 10 cm x 10 cm on the left side of the ewe was clipped with a set of small animal clippers fitted with a fine comb (Oosti 001 blades). The wool clipped was recovered quantitatively and placed in a small plastic bag. Each side and one diagonal of the rectangular patch were measured with calipers to allow calculation of the area of the patch.

On day 67, the wool was clipped from within the previously prepared midside area to measure wool growth by each ewe after shearing.

Wool samples were stored in opened plastic bags in a room with a relative humidity of 65 % until required for weighing and scouring.

3.2.6. Weighing ewes and lambs

Ewes were weighed on days 0 and 67 after shearing. Lambs were weighed within 24 hours of birth and with the ewes on day 67 after shearing.

Electronic scales (Tru-test AG 300) with a 200 kg suspension cell were used for weighing ewes and older lambs. Newborn lambs were weighed using a conventional spring balance.

Lamb growth rate (LGR; g/d) was calculated using the formula :

$$LGR = (W2 - W1)/a$$

where ;

W2 = lamb weight at day 67 (kg)

W1 = Lamb birth weight (kg)

a = lamb age (days; 67-day of lambing)

3.2.7. Measurement of herbage mass

Herbage mass was measured to determine the relationship between the amount of pasture offered and the pasture eaten by the ewes during the

intake measurement periods. Twice weekly measurement of herbage height commenced on day -2 and continued to day 20 corresponding to the collection of faecal samples. Measurement of herbage height was carried out by an Ellibank rising plate meter (Early and McGowan, 1979). The plate meter was calibrated against a standard cutting method (Whatter and Evans, 1979). On day 4 a meter reading was taken at 20 sites in the paddock and then at each site an area 30 cm x 60 cm or (0.18 m^2) was clipped to ground level with a portable shearing plant and the grass collected quantitatively. After cutting, the samples were washed to remove soil contamination and then dried at 70-80 ^oC for 36 hours and weighed. The dry matter yield (kg DM/ha) was calculated as follows.

$$HM = 10,000 \times X/Y$$

where;

HM = herbage mass (kg DM/ha)

X = dried weight of pasture (kg) collected at each site

Y = 0.1800 m^2 (area clipped)

The plate meter was calibrated by regressing the meter reading on the measured pasture mass :

$$HM = a + bX$$

where;

HM = herbage mass (kg DM/ha)

a = 200 (kg DM/ha)

b = 160 (kg DM/ha)

X = meter reading

The relationship between herbage dry matter (kg DM/ha) and pasture meter reading at each site is shown in Figure 1 of appendix A.

3.3. Analytical methods

3.3.1. Plasma metabolites

Plasma metabolites were measured on a Cobas Fara II autoanalyzer (F. Hoffmann L.A Roche Ltd., Diagnostics Division, CH-4002 Basel, Switzerland) following the manufacturers recommendations. Inter and intra assay coefficients of variation for glucose, NEFA, 3-hydroxybutyrate, urea and creatinine were 4.55, 1.92; 3.64, 1.03; 1.03, 2.22; 1.3, 2.3 and 1.4, 1.0, respectively.

3.3.1.1. Glucose

Plasma glucose was determined with an enzymatic colourimetric assay using glucose oxidase and 4-aminophenazone. In the presence of

peroxidase, the hydrogen peroxide formed by the oxidation of glucose by glucose oxidase effects the oxidative coupling of hydroxybenzoic acid and 4-aminophenazone to form a red coloured quinoneimine derivative. The colour intensity is proportional to the glucose concentration and is determined by monitoring the absorbance at 550 nm.

3.3.1.2. NEFA (non esterified fatty acids)

Plasma NEFA concentrations were measured using an enzymatic colourimetric method (Wako NEFA C kit) which was modified by Scott (1989) for use on the Cobas Fara. This method is based on the enzymatic activation (acyl-CoA synthetase (ACS)) of plasma NEFA to coenzyme A esters. The acyl-CoA is oxidased by acyl-CoA oxidase (ACOD) to produce hydrogen peroxide. The presence of peroxidase and hydrogen peroxide allows the oxidative condensation of 3 methyl-N-ethyl-N-(B-hydroxyethy)-aniline (MEHA) with 4-amino-antipyrine to form a purple quinone product, the optical density of which is measured at 550 nm.

3.3.1.3. 3-hydroxybutyrate

The assay for 3-hydroxybutyrate followed the method described by Williamson and Mellanby (1974) as modified by Mackenzie *et al.* (1989). The method was further modified (M.F. Scott, pers. com.) for use on the Cobas Fara as follows.

Plasma samples were diluted with deionized water in the sample portion of a cuvette. The reagent mixture which contained the enzyme 3-hydroxybutyrate dehydrogenase was pipetted into the reagent portion of the cuvette. After centrifugal mixing, absorbance measurements at 340 nm were taken over a period. The absorbance increased at a rate proportional to the synthesis of NADH from NAD. The change in absorbance of the samples was compared to that of a standard curve and results were calculated to give the concentration of 3-hydroxybutyrate.

3.3.1.4. **Urea**

The measurement of urea was based on the coupling of the urease/glutamate dehydrogenase (GLDH) reactions.

$$\text{Urea} + 2\ H_2O \xrightarrow{\text{urease}} 2\ NH_3 + CO_2$$

$$NH_4^+ + \text{2-oxoglutarate} + \text{NADH} \xrightarrow{\text{GLDH}} \text{L-glutamate} + NAD^+ + H_2O$$

The decrease in the NADH concentration is directly proportional to the urea concentration and is measured photometrically at 340 nm.

.3.1.5. Creatinine

$$\text{Creatinine} + \text{picric acid} \xrightarrow[\text{pH}]{\text{alkaline}} \text{red complex}$$

The reaction between creatinine and picric acid will produce a red omplex. The rate of formation of the red coloured complex is measured t 520 nm. Starting with the time of first reading at 35 seconds after ıixing, the reaction rate is followed over a 90 second interval. A urfactant was added to suppress protein interference.

ł.3.2. Wool production

Greasy wool production was measured by weighing the wool sample collected 67 days after shearing from the midside patch (3.2.5) after at least 48 hours equilibration at 65 % RH.

Clean wool growth was measured by the following procedure :

a. A sample, representative of the bulk was weighed, numbered and placed in a net cloth bag.

b. The bag containing the sample was placed in the first of four bowls of the scouring machine and the mechanical agitation turned on.

c. At the end of three minutes the agitator was carefully swung back, the basket raised to above the liquid level and the sample passed

through squeeze rollers taking care to keep the sample entirely intact and spread evenly on the feed-in tray of the rollers.

d. This operation was repeated in each of the remaining bowls with the wringer being dispensed with after bowl 3.

e. Bowls 1, 2, and 3 contained 32, 16 and 16 ml of the detergent teric GN 9 in 36 litres of water at temperatures of 60, 55 and 50 ^{o}C and pH 8 respectively; while in bowl 4 cold water was used at pH 7.5.

f. From bowl 4, the sample was hand wrung and placed in a hydro-extractor and spun for at least one minute.

g. The sample was then spread evenly in a metal tray and placed in the bottom compartment of a drying oven at 62 ^{o}C . It was moved to the top compartment with the arrival of the next sample after approximately 6 minutes.

h. Following drying the samples were removed and placed in a humidity room at 65 % RH for 48 hours.

i. The samples were then weighed in the humidity room.

j. Wool growth was calculated as the scoured (clean) weight of wool grown per square centimetre per day.

3.3.3. Analysis of feed

The digestibility of the feed consumed by the ewes was estimated from pasture samples of approximately 50 g collected by hand plucking while observing the ewes grazing. Samples collected on days 8, 13 and 20 of the experiment, were analyzed for nitrogen content, dry matter (DM)

and *in vitro* digestibility using the method described by Roughan and Holland (1979). The samples were calibrated against six pasture standards of known *in vivo* digestibility. The chemical composition and the *in vitro* digestibility of the pasture are shown in Table 1 of appendix A.

3.3.4. Chromium analysis

Chromium concentration in faeces was measured using the technique described by Parker *et al.* (1989);

1. Nine faecal samples collected on consecutive days from each ewe were dried in an oven at 80 ^{o}C for 72 h.

2. Approximately 0.5 g DM of each faecal sample collected over 3 consecutive days were weighed and mixed together. The combined samples, three for each ewe, were put into tared and numbered 25 ml pyrex beakers.

3. The beakers were placed in an oven at 105 ^{o}C to dry for 24 h.

4. After drying the beakers were weighed to determine the dry matter weight and then the samples were ashed at 550 ^{o}C in a furnace for 12 h.

5. The beakers and ash were reweighed and anti-bumping granules, plus 6 ml of acid digestion mixture ($MnSO_4$/posphoric acid solution) were added.

6. The beakers were covered with glass to prevent evaporation of the mixture and heated to boiling (140 ^{o}C) in an aluminium heating block for 90 minutes.

7. The beakers were removed from the block, allowed to cool to below 100 ^{o}C and then 3 ml of 4.5 % potassium bromate was added. The beakers were returned to the heating block, covered and digested to a final temperature of 210 ^{o}C.

8. After approximately 45 minutes the beakers were removed from the block and allowed to cool before their contents were quantitatively transferred into 50 ml flat bottom volumetric flasks.

9. The digest volume was made up to 50 ml with distilled water, shaken to throughly mix and allowed to settle for 24 h.

10. A 10-15 ml aliquot was poured off into a small plastic bottle. By only taking small amounts from the top, a clear sample with minimal suspended material was obtained for spectrophotometry.

3.4. Environmental measurements

Environmental parameters were measured from the beginning of the experiment up to day 67.

3.4.1. Temperature and wind velocity

Maximum and minimum air temperatures (^{o}C) were recorded using a mercury thermometer and wind velocity (km/h) was recorded from an

anometer positioned in the paddock in which the sheep were grazed. Readings were recorded once daily at 8.00 am and are presented in Table 2 of appendix A.

3.4.2. Relative humidity, rainfall and sunshine

Data on the relative humidity, rainfall and sunshine for the Palmerston North field were obtained from the meteorological station of the DSIR, Palmerston North. The environmental relative humidity, rainfall and sunshine are shown in Table 2 of appendix A.

3.5. Statistical analysis

All data were analysed by a general linear model (GLM) using the statistical analysis system (SAS) computing package (SAS Institute, 1985).

Charts were drawn using the microsoft chart program.

The model used to define the data of faecal output; feed and energy intake was :

$$Y_{ijk} = \mu + \beta_1 (X_1) + \beta_2 (X_2) + A_i + B_j + e_{ijk}$$

Where ;

Y_{ijk} = The observation in the i^{th} pre-lamb shearing method, j^{th} pregnancy status and k^{th} ewe.

μ = The general mean.

X_1 = Live weight of the j^{th} ewe.

X_2 = Lambing date of the j^{th} ewe.

β_1 = Coefficient of regression associated with X_1.

β_2 = Coefficient of regression associated with X_2.

A_i = The effect of the i^{th} pre-lamb shearing method (i=1,2 where 1 = conventional and 2 = cover).

B_j = The effect of the j^{th} pregnancy status.

e_{ijk} = The residual error of the i^{th} pre-lamb shearing method, j^{th} pregnancy status and k^{th} ewe. It is assumed that e_{ijk} is normally distributed with mean 0 and variance δ^2.

The rectal temperature and metabolic effects were analyzed using the following model :

$$Y_{ij} = \mu + \beta_1 (X_1) + \beta_2 (X_2) + A_i + e_{ij}$$

Where ;

Y_{ij} = The observation in the i^{th} pre-lamb shearing method, j^{th} ewe for the repeated measured analysis and the differences between 1,3,7 and 14 days after shearing and the mean of the consecutive 2 days before shearing.

μ = The general mean.

X_1 = Live weight of the j^{th} ewe.

X_2 = Lambing date of the j^{th} ewe.

β_1 = Coefficient of regression associated with X_1.

β_2 = Coefficient of regression associated with X_2.

A_i = The effect of the i^{th} pre-lamb shearing method (i=1,2 where 1 = conventional and 2 = cover).

e_{ij} = The residual error of the i^{th} pre-lamb shearing method and j^{th} ewe. It is assumed that e_{ij} is normally distributed with mean 0 and variance δ^2.

The lamb birth weight and its growth rate were analyzed using this model.

$$Y_{ijk} = \mu + A_i + B_j + C_k + (AB)_{ij} + (AC)_{ik} + (BC)_{jk} + e_{ijk}$$

Where ;

Y_{ijk} = The observation in the i^{th} pre-lamb shearing method, j^{th} pregnancy status and k^{th} sex.

μ = The general mean.

A_i = The main effect of the i^{th} pre-lamb shearing method (i=1,2 where 1 = conventional and 2 = cover).

B_j = The main effect of the j^{th} pregnancy status (j=1,2,3 where 1=non pregnant, 2=single and 3=twin).

C_k = The main effect of the k^{th} sex (k=1,2 where 1=male, 2=female).

$(AB)_{ij}$= The effect of the interaction between the i^{th} method of pre-lamb shearing and the j^{th} pregnancy status.

$(AC)_{ik}$= The effect of the interaction between the i^{th} method of pre-lamb shearing and the k^{th} sex.

$(BC)_{jk}$= The effect of the interaction between the j^{th} pregnancy status and k^{th} sex.

e_{ijk} = The residual error of the i^{th} pre-lamb shearing method, j^{th} pregnancy status and k^{th} sex. It is assumed that e_{ijk} is normally distributed with mean 0 and variance δ^2.

The live weight of ewes at the time of shearing (d 0) were analyzed using this model.

$$Y_{ijk} = \mu + A_i + B_j + C_k + (AB)_{ij} + (AC)_{ik} + (BC)_{jk} + e_{ijk}$$

Where ;

Y_{ijk} = The observation in the i^{th} pre-lamb shearing method, j^{th} pregnancy status and k^{th} rearing rank.

μ = The general mean.

A_i = The main effect of the i^{th} pre-lamb shearing method (i=1,2 where 1 = conventional and 2 = cover).

B_j = The main effect of the j^{th} pregnancy status (j=1,2,3 where 1=non pregnant, 2=single and 3=twin).

C_k = The main effect of the k^{th} rearing rank (k=1,2,3 where 1=no, 2=single and 3=twin reared lamb).

$(AB)_{ij}$= The effect of the interaction between the i^{th} method of pre-lamb shearing and the j^{th} pregnancy status.

$(AC)_{ik}$= The effect of the interaction between the i^{th} method of pre-lamb shearing and the k rearing rank.

$(BC)_{jk}$= The effect of the interaction between the j^{th} pregnancy status and k^{th} rearing rank.

e_{ijk} = The residual error of the i^{th} pre-lamb shearing method, j^{th} pregnancy status and k^{th} rearing rank. It is assumed that e_{ijk} is normally distributed with mean 0 and variance δ^2.

The wool growth and live weight of ewes on day 67 after shearing were defined using the same model for the live weight but the initial live weight was included as a covariant.

The results are reported as means ± standard error of the mean.

RESULTS

IV. RESULTS

4.1. Faecal output; feed and energy intake

Mean values for faecal output and estimates of intake of feed and energy are presented in Table 4.1.

Faecal output and feed intake of organic matter (OM) and dry matter (DM) in period 1 of the ewes shorn with the cover comb were higher than those for the ewes shorn with a conventional comb. Faecal output and feed intake was similar between two methods of pre-lamb shearing in period 2. However, in period 3, the ewes shorn by the conventional comb had higher average faecal outputs and feed intakes than cover shorn ewes (Table 4.1).

The effect of method of pre-lamb shearing and pregnancy status on faecal output, feed and energy intake in period 1, 2 and 3 were not statistically different.

Table 4.1. Comparison of mean (±SE) dry matter (DM), organic matter (DM) and energy intake and faecal output of 10 ewes shorn by a conventional method and 10 ewes shorn with a cover comb in three periods.

		Pregnancy status	Treatments					
			Period 1		Period 2		Period 3	
			Conventional	Cover	Conventional	Cover	Conventional	Cover
Faecal output	OM(g)	Single	412±46	533±33	415±51	458±63	374±37	388±58
		Twin	448±140	471±31	554±25	432±146	506±67	305±14
	DM(g)	Single	665±73	837±56	685±87	767±110	592±67	569±84
		Twin	730±200	748±64	961±74	705±230	798±94	446±25
Intake	OM(g)	Single	1,801±201	2,330±144	1,834±224	2,026±280	1,507±149	1,562±233
		Twin	1,955±612	2,056±137	2,450±112	1,910±646	2,040±269	1,228±57
	DM(g)	Single	2,348±257	2,953±198	2,350±297	2,630±377	1,888±215	1,814±267
		Twin	2,574±705	2,639±226	3,295±254	2,418±790	2,545±298	1,422±80
Energy	(MJ)	Single	26.0±2.8	32.7±2.2	25.3±3.2	28.3±4.1	20.1±2.3	19.3±2.8
		Twin	28.5±7.8	29.2±2.5	35.5±2.8	26.0±8.5	27.0±3.2	15.1±0.8

Significance levels :

Pregnancy status	NS	NS	NS
Treatments	NS	NS	NS

4.2. Rectal Temperature

The rectal temperatures (^{o}C) of the ewes declined in both groups on days 1, 3, 7, and 14 after shearing in comparison with pre-shearing values (Table 4.2, Figure 4.1). The effect of method of pre-lamb shearing on rectal temperature of ewes within days was small and not significant but rectal temperatures were consistently higher on average in the ewes shorn with the cover comb.

A repeated measured analysis did not show any statistically significant effects of treatment or time on rectal temperatures.

Table 4.2. Comparison of the mean (±SE) rectal temperature (^{o}C) of 30 ewes shorn with conventional combs and 30 ewes shorn with cover combs two days before shearing and 1,3,7, and 14 days after shearing.

Treatments	Time from shearing (days)					
	-2	-1	1	3	7	14
Conventional	39.08±0.04	39.22±0.05	38.90±0.10	38.84±0.06	38.78±0.05	38.85±0.04
Cover	39.27±0.06	39.32±0.05	38.98±0.07	38.92±0.05	38.81±0.04	38.87±0.05
Significance levels :						
Between treatments within days			NS	NS	NS	NS

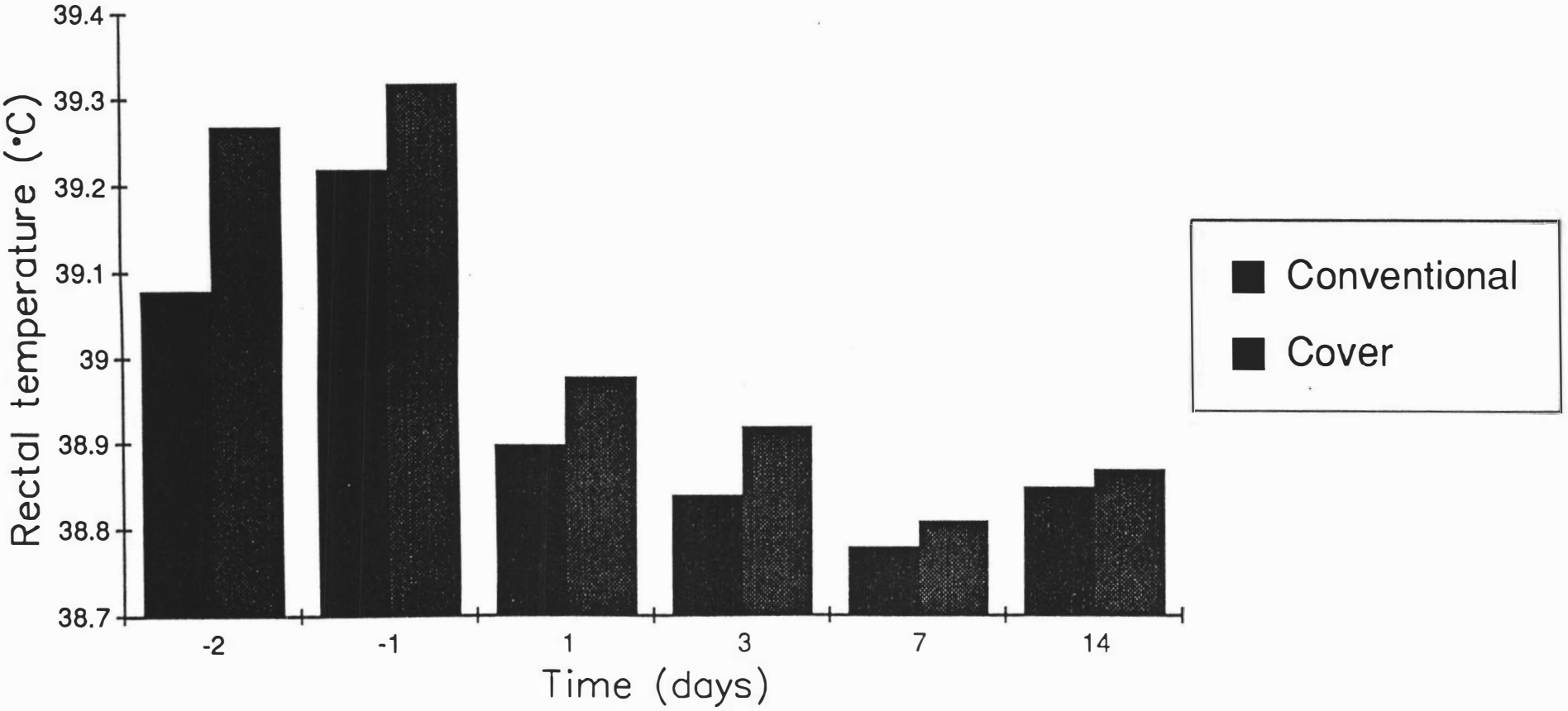

Figure 1. Mean rectal temperatures (^{o}C) of 30 ewes shorn with conventional combs and 30 ewes shorn with cover combs two days before shearing and 1,3,7,14 days after shearing

4.3. Lamb birth weight and average daily gain

There were 69 lambs born in total from both groups. Birth weights were recorded for 38 lambs from the cover shorn ewes and 31 lambs from the conventional shorn group but 5 lambs died soon after lambing and another 3 before 67 days after shearing.

The effect of birth rank was highly significant ($P<0.0002$) on birth weight and lamb growth rate ($P<0.07$), while method of shearing and sex were not significant on birth weight and lamb growth rate (Table 4.3). Overall the conventional group (5.62 kg), males (5.6 kg) and singles (5.9 kg) were heavier than the cover group (5.44 kg), females (5.4 kg) and twins (5.0 kg), respectively, at birth and these differences were reflected in greater growth rates in the conventional group, the males and single lambs (Table 4.3).

Table 4.3. Comparison of the mean (±SE) lamb birth weight (kg) and the average daily gain (g/d) of lambs of conventional and cover comb shorn ewes.

Treatments	Sex	Birth rank	Birth weight (kg)	Average daily gain (g/d)
Conventional	Male	Single	6.03±0.21	313±14
		Twin	5.07±0.38	283±14
	Female	Single	6.17±0.22	282±11
		Twin	4.66±0.53	274±32
Group mean			5.62	288
Cover	Male	Single	5.77±0.33	303±18
		Twin	5.34±0.18	274±16
	Female	Single	5.68±0.28	271±15
		Twin	4.91±0.23	257±15
Group mean			5.44	276

Significance levels :		
Shearing	NS	NS
Sex	NS	NS
Birth rank	P<0.0002	P<0.07
Shearing*Sex	NS	NS
Shearing*Birth rank	NS	NS
Sex*Birth rank	NS	NS

4.4. Metabolic effects

The effect of method of pre-lamb shearing on the concentration of plasma metabolites of ewes before and after shearing is presented in Table 4.4 and the graphs are presented in Figures 4.2;4.3;4.4;4.5, and 4.6 for each of the metabolites.

A repeated measures analysis showed a significant ($P<0.03$) effect of time but not treatment, on plasma glucosa concentrations. Glucose concentration (Table 4.4, Figure 4.2) increased on days 1 and 3 after shearing in both the conventional and cover groups but the difference between groups was not statistically significant.

The effects of treatment ($P<0.003$) and time ($P<0.002$) were significant in a repeated measures analysis on the concentration of NEFA in plasma. In both groups the concentration of NEFA in the plasma increased on day 1 following shearing and remained elevated on day 14 (Table 4.4, Figure 4.3). The increase was greater in the conventional group on days 1 and 3 after shearing and the differences between the groups were highly significant ($P<0.0007$ and $P<0.02$ respectively), on these days.

The effects of time ($P<0.0001$) and methods of pre-lamb shearing were significant ($P<0.01$) on 3-hydroxybutyrate concentration in a repeated measures analysis. The concentration of 3-hydroxybutyrate reached peak values on day 1 after shearing and then decreased so that

on days 7 and 14 the concentrations were lower than they were before shearing (Table 4.4, Figure 4.4). The plasma 3-hydroxybutyrate concentrations were significantly greater in the conventionally shorn group on day 1 ($P<0.002$) and day 3 ($P<0.03$).

The effect of time was statistically significant ($P<0.01$) in a repeated measures analysis of urea concentration. Plasma urea concentration decreased slightly on days 3 and 7 after shearing in both the groups, however there were no significant difference between the groups.

The effect of time was significant ($P<0.002$) in a repeated measures analysis of creatinine concentration. Plasma creatinine concentration decreased on days 3 and 7 in both the conventional group and the cover group. Differences between groups were not statistically different within days.

Table 4.4. Comparison of the mean (±SE) concentration of various metabolites in the plasma of ewes from two groups each of 30 ewes shorn either with conventional or cover combs two days before shearing and 1,3,7 and 14 days after shearing.

Treatments	Blood parameter	Day of blood sampling					
		-2	-1	1	3	7	14
Conventional	Glucose (mmol/l)	3.28±0.07	3.34±0.08	3.55±0.13	3.58±0.10	3.05±0.06	3.28±0.09
	NEFA (meq/l)	0.22±0.02	0.20±0.02	0.39±0.03	0.35±0.03	0.33±0.03	0.32±0.03
	3-OH-B (mmol/l)	1.16±0.07	1.23±0.07	1.52±0.07	1.38±0.08	1.08±0.07	1.06±0.04
	Urea (mmol/l)	8.27±0.18	8.47±0.25	10.26±0.33	8.33±0.23	7.52±0.20	9.23±0.33
	Creatinine (µmol/l)	9.10±0.23	8.50±0.19	8.50±0.21	7.28±0.17	7.00±0.18	8.60±0.30
Cover	Glucose (mmol/l)	3.40±0.09	3.29±0.09	3.65±0.12	3.52±0.11	2.95±0.06	3.37±0.14
	NEFA (meq/l)	0.25±0.02	0.21±0.02	0.31±0.07	0.28±0.02	0.31±0.03	0.35±0.03
	3-OH-B (mmol/l)	1.33±0.07	1.33±0.08	1.42±0.07	1.27±0.05	1.03±0.05	1.09±0.06
	Urea (mmol/l)	7.71±0.25	8.41±0.25	10.37±0.33	8.22±0.25	7.04±0.16	9.30±0.28
	Creatinine (µmol/l)	8.63±0.17	8.26±0.15	8.27±0.23	6.82±0.18	6.48±0.16	8.84±0.38

Significance levels :

Between treatments within days

Glucose	NS	NS	NS	NS
NEFA	P<0.0007	P<0.02	NS	NS
3-OH-B	P<0.002	P<0.03	NS	NS
Urea	NS	NS	NS	NS
Creatinine	NS	NS	NS	NS

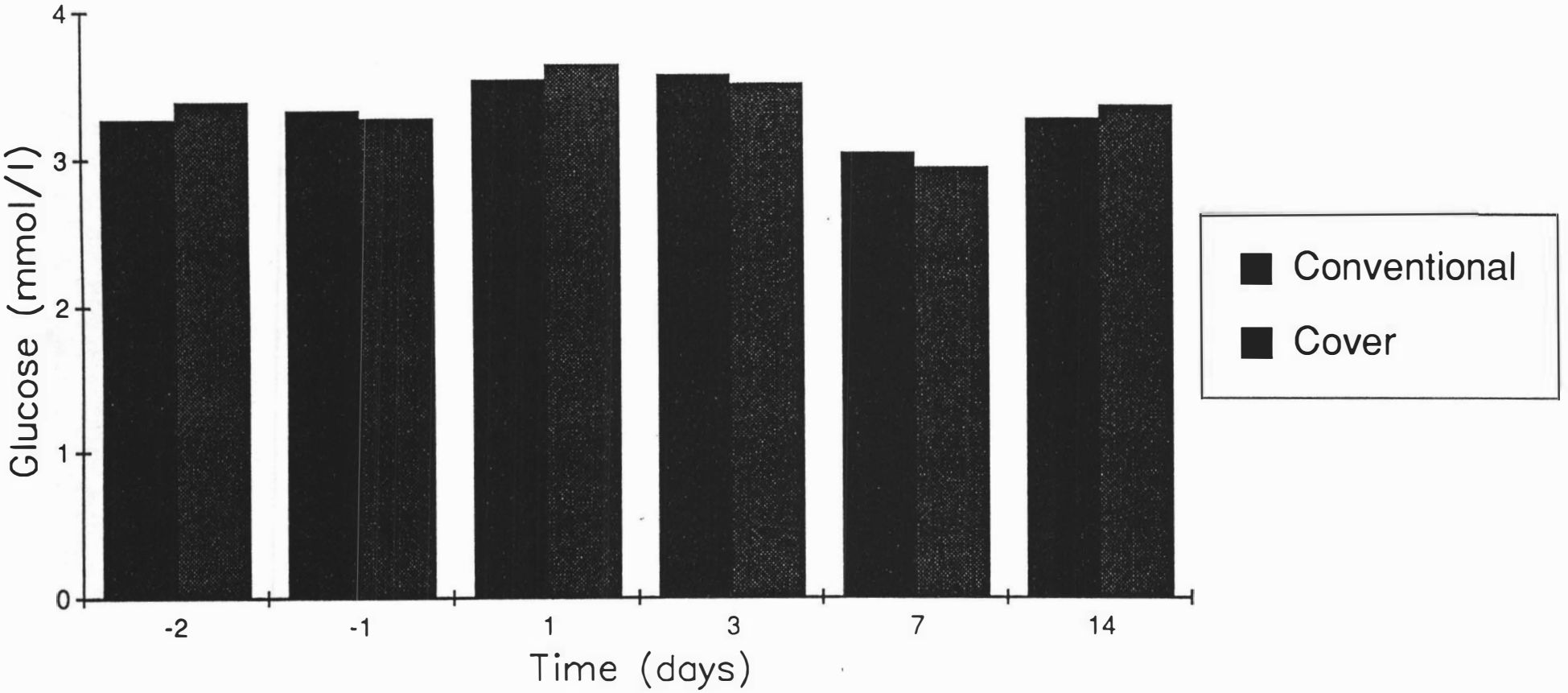

Figure 2. Mean glucose concentrations (mmol/l) of 30 ewes shorn with conventional combs and 30 ewes shorn with cover combs two days before shearing and 1,3,7,14 days after shearing

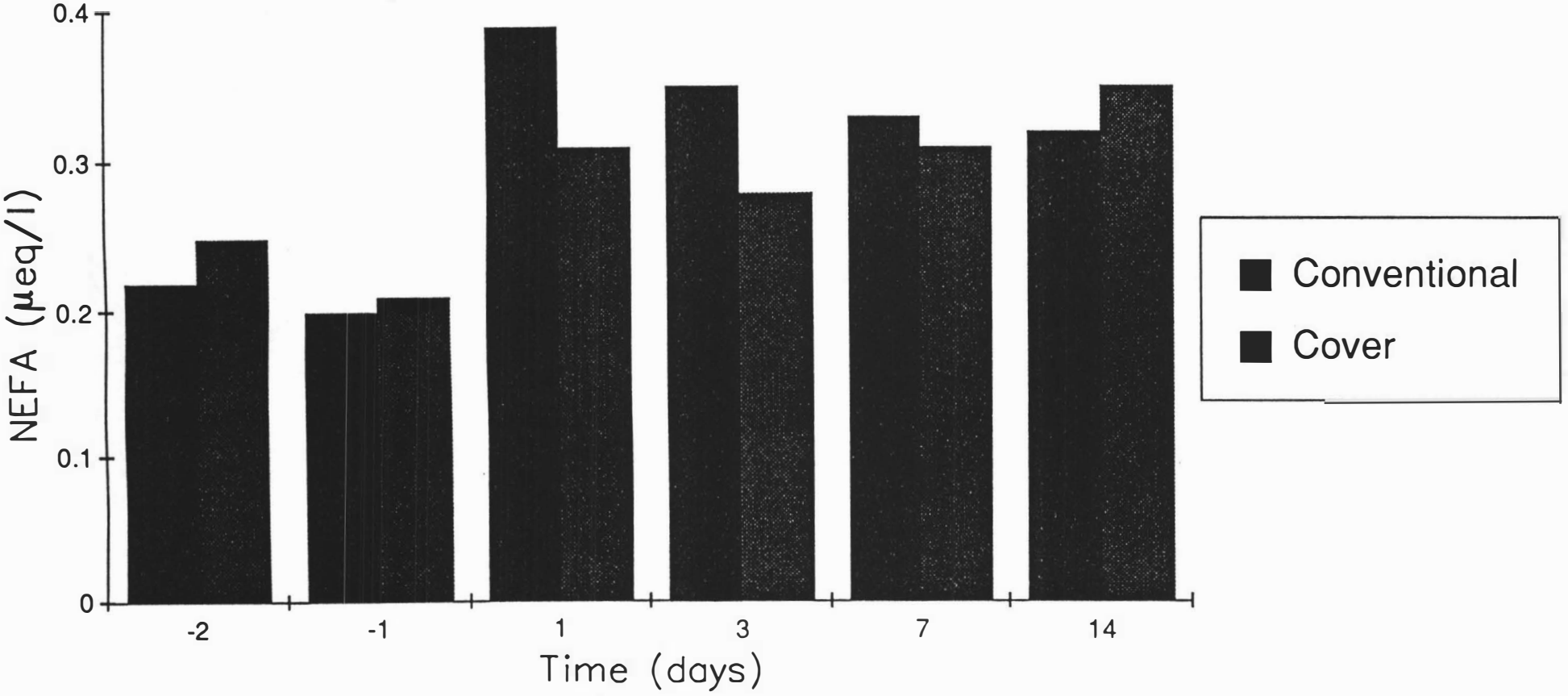

Figure 3. Mean non esterified fatty acid (NEFA) concentrations (µmol/l) of 30 ewes shorn with conventional combs and 30 ewes shorn with cover combs two days before shearing and 1,3,7,14 days after shearing

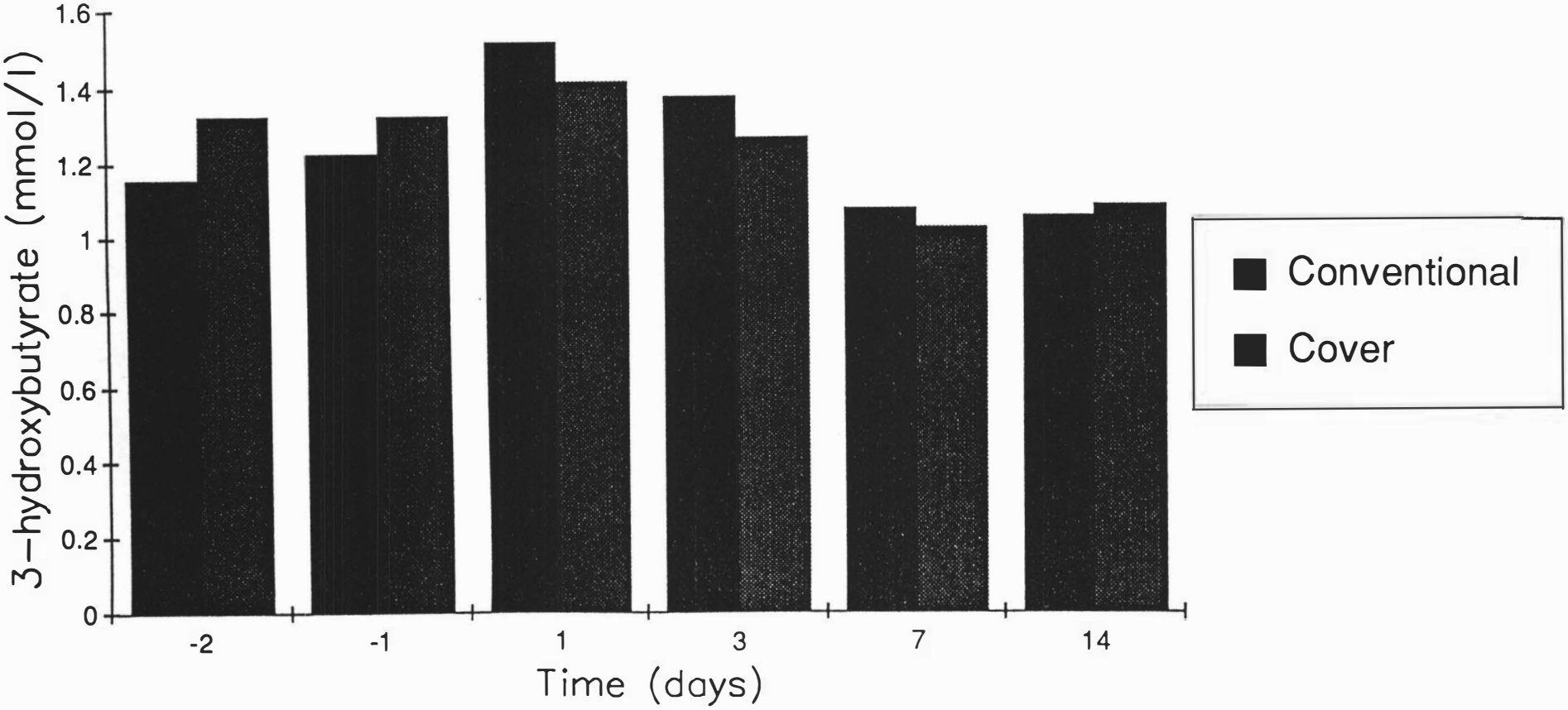

Figure 4. Mean 3-hydroxybutyrate concentrations (mmol/l) of 30 ewes shorn with conventional combs and 30 ewes shorn with cover combs two days before shearing and 1,3,7,14 days after shearing

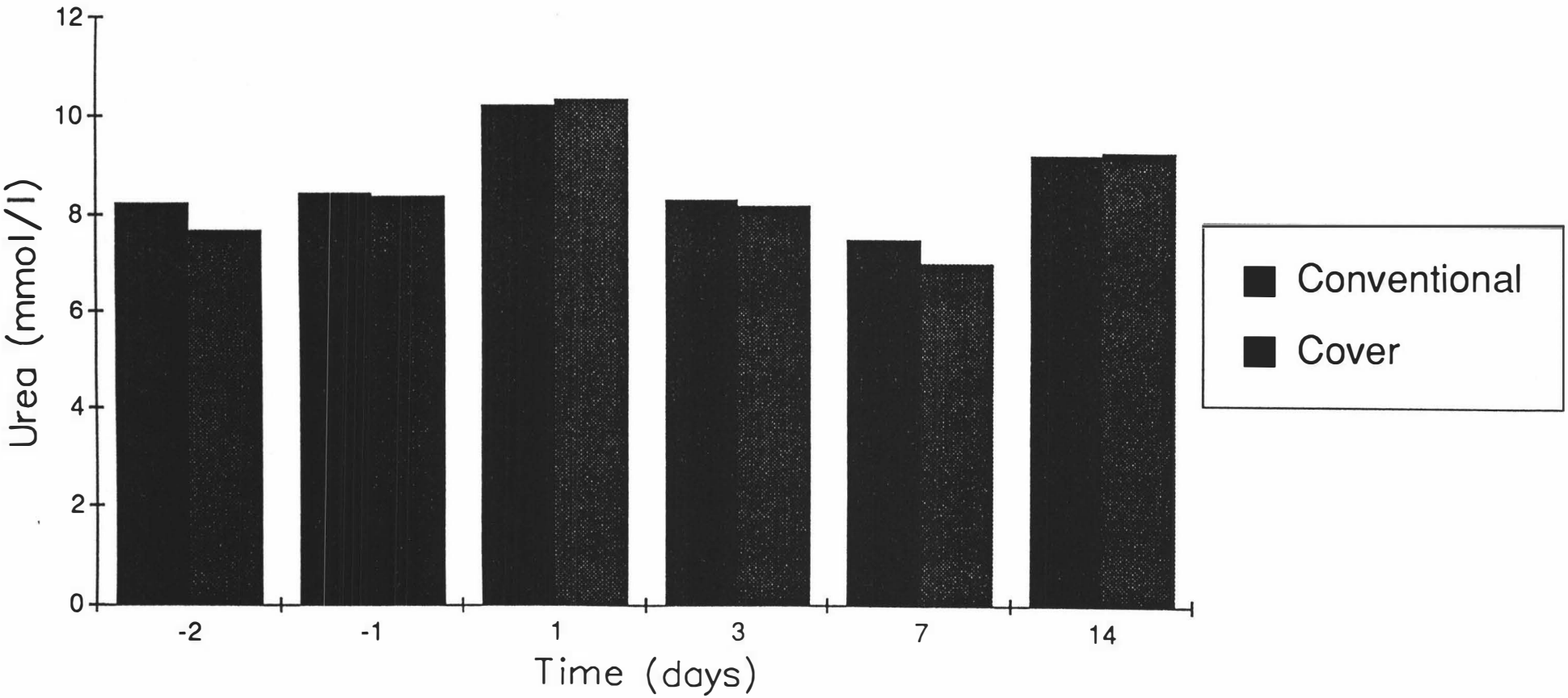

Figure 5. Mean urea concentrations (mmol/l) of 30 ewes shorn with conventional combs and 30 ewes shorn with cover combs two days before shearing and 1,3,7,14 days after shearing

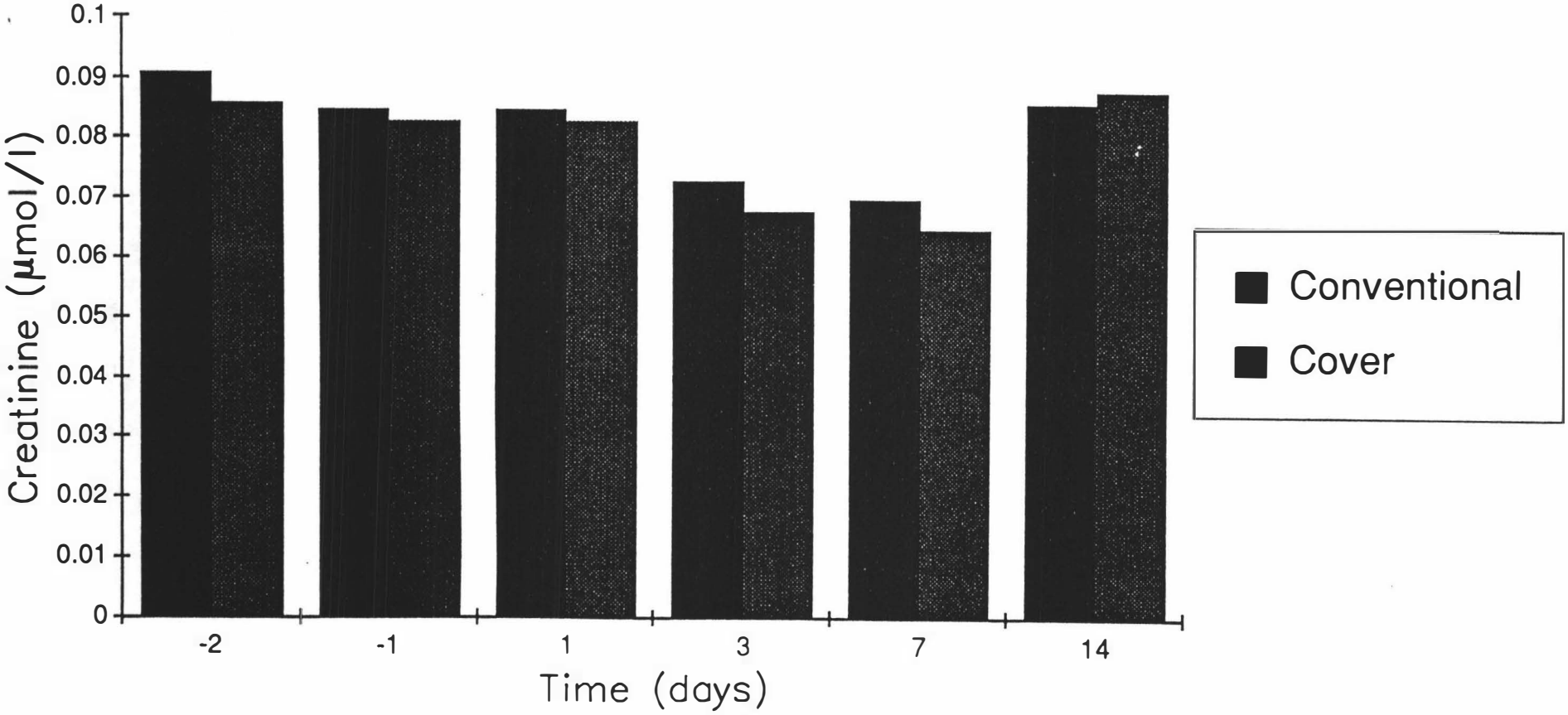

Figure 6. Mean creatinine concentrations (µmol/l) of 30 ewes shorn with conventional combs and 30 ewes shorn with cover combs two days before shearing and 1,3,7,14 days after shearing

4.5. Wool growth and ewe live weight

Wool growth as measured by the mid-side patch method is presented in Table 4.5.

Wool grown (50 g/cm^2) by ewes shorn by the conventional method was 6 % lower than that grown (53 g/cm^2) by the group shorn by the cover method . Mid-side patch wool growth was 61.5, 52.6 and 43.5 g/cm^2 in the ewes that had reared no lambs, a single lamb or twin lambs, respectively. These differences in wool production were not statistically significant.

The average liveweight of the ewes at the time of shearing (d 0) was similar (58.0 kg) in the conventional and cover groups. By day 67 after shearing both groups had gained approximately 6 kg live weight and the difference between groups was not statistically significant.

Ewe liveweight was greatest in the twin pregnant ewes (61.8 kg) on day 0 followed by single pregnant ewes (57.4 kg) and dry ewes (54.0 kg), but by day 67, ewes which had not reared a lamb (66.3 kg) were heaviest, followed by the ewes with single reared lamb (63.5 kg) and twin reared lamb (62.3 kg), respectively.

Table 4.5. The mean (±SE) mid-side patch wool growth on day 67 after shearing and ewe live weights on days 0 and 67 after shearing of ewes shorn with conventional comb and with cover combs.

Treatments	Bearing status	Rearing rank	n	Wool growth	Ewe live weight (kg)			
					day 0		day 67	
				g/cm^2	n		n	
Conventional	Dry	-	7	59±6	7	54.3±2.7	7	64.9±4.5
	Single	1	16	50±5	17	57.3±1.7	16	63.7±2.2
	Twin	1	2	45±3	2	63.6±2.0	2	63.3±9.9
		2	4	38±8	4	64.2±3.5	4	62.8±1.9
Group mean		4	29	50	30	57.9	29	63.9
Cover	Dry	-	2	70±1	2	52.8±0.4	2	72.3±0.5
	Single	0	1	77±0	1	57.2±0	1	64.0±0
		1	16	54±5	16	57.5±1.8	16	64.3±2.1
	Twin	1	3	35±3	3	59.5±4.6	3	58.1±2.6
		2	6	50±1	6	60.3±1.8	6	62.1±2.2
Group mean		4	28	53	28	57.9	28	63.7
Significance levels :								
Treatments				NS		NS		NS
Bearing rank				NS		NS		P<0.01
Rearing rank				NS		NS		NS
Treatments*Bearing rank				NS		NS		NS
Treatments*Rearing rank				NS		NS		NS

DISCUSSION

DISCUSSION

1. Ewe live weight, feed intake, lamb birth weight and average daily in

The changes in ewe live weight in both groups from shearing time (d
1 to day 67 after lambing were similar and reflected the lack of
ifferences in organic matter (OM) and dry matter (DM) intake measured
n the ewes immediately after shearing (Table 4.1). However, the
omparison was made between two methods of pre-lamb shearing and a third
roup of ewes which were not shorn would have been needed to detect the
verall effect of shearing on feed intake and live weight changes. This
as been investigated in other experiments with variable results. Thus
ntake of feed by ewes in late pregnancy sometimes declines (Forbes,
986), leading to ketosis and poor foetal growth. Symonds *et al.* (1986)
eported that intake and live weight of ewes shorn on day 56 before
lambing and post lambing did not increase in comparison to unshorn ewes.
Whereas in most experiments, shearing stimulates voluntary feed intake
of pregnant and non pregnant sheep (Wodzicka-Tomaszewska , 1963; Webster
and Lynch, 1966; Ternouth and Beattie, 1970; Maund, 1980; Russel *et al.*
1985 and Symonds *et al.* 1986). Overall an increased maternal food intake
can generally be expected following shearing, which may result in better
foetal nutrition (Austin and Young, 1977).

Previous studies have shown that shearing pregnant ewes during late
pregnancy increases lamb birth weight (Nedkvitne, 1972, Austin and

Young, 1977; Maund, 1980; Thompson *et al*. 1982, Russel *et al*. 1985 and Symonds *et al*. 1986) although Symonds *et al*. (1988a) were unable to detect any effect of pre-lamb shearing on lamb birth weight. In the present experiment, the mean birth weight of lambs in the conventional group was only 3 % higher than that of the cover group. Thus, whatever the effect of pre-lamb shearing on the birth weight of the lambs there was no differential effect of the two treatments and there is no reason therefore to prefer one method to the other on this basis.

The average birth weight of single lambs from conventionally shorn ewes was 7 % greater in comparison with the cover group but there was no difference in the weight of twins from the two groups. Although the difference in weight of the single lambs is not significant it is similar to a report by Thompson *et al*. (1982) that when ewes were exposed to chronic cold during pregnancy birth weight of single lambs was increased but not for twin lambs. Therefore, the greater birth weight of single lambs from ewes shorn with the conventional comb may be due to a greater cold stress put on these ewes. Greater numbers would be needed, however to prove it.

The growth rates of lambs from the two groups were not significantly different. In general heavier lambs grew more quickly than lighter lambs perhaps reflecting differences in nutritional status of their dams and hence milk production or differences between lambs in their thermal insulation (Austin and Young, 1977).

In this experiment, the effect of birth rank on lamb birth weight was highly significant ($P<0.01$) which is in agreement with Thompson *et*

al. (1982) and reflects the greater demand for nutrients by twin foetues. Again the heavier lambs at birth, generally single lambs, grew more quickly than lighter lambs.

5.2. Rectal temperature

The objective of this experiment was to demonstrate that the use of the cover comb reduced the severity of the cold stress imposed by shearing. Stainer *et al.* (1984) have postulated that severity of a cold stress either from low environmental temperatures or induced by pre-lamb shearing can be assessed by measuring the fall in rectal temperature in pregnant ewes. Even though sheep are homeothermic animals and can maintain their deep body temperature, under extreme conditions rectal temperature will fall. The extent of the fall will depend on environmental conditions, including temperature, wind and rain, and the thermoregulatory ability of the ewe.

In this experiment, the sheep were kept in the field where the temperature ranged from 3.7 to 14 ^{o}C during the period when rectal temperatures were measured. Furthermore over this period conditions remained dry and the wind chill factors were moderate (Table 2 of appendix A). Thus the cold stress experienced at shearing was moderate. In comparison with the two days before shearing the rectal temperatures were slighly lower in both groups after shearing although a time series analysis of the data does not indicate a significant variation of

temperatures over time. Measurement on a group of unshorn ewes over the same period would have increased the sensitivity of the experiment. Nevertheless the data are consistent with the ewes from the group shorn with the cover comb being subjected to slighly less of a cold stress in that their body temperature fell less after shearing than that of the group shorn with the conventional comb. Again, however, the effect of treatment on body temperature was not statistically significant.

5.3. Metabolic effects

Measuring rectal temperature is a direct method of assessing whether the animal is able to adjust to a cold stress. In adjusting, however, the energy requirements are increased to provide extra heat (Halliday, 1969; Davey and Holmes, 1977 and Symonds *et al.* 1986). Thus, Graham *et al.* (1959) observed that in shorn wethers, heat production (HP) increased linearly with a decrease in environmental temperature below 23 ^{o}C irrespective of feeding level. Furthermore, energy requirements of shorn pregnant ewes were 28 % higher than those of unshorn pregnant sheep and 2.14 times higher in sheep exposed to 0 ^{o}C compared with those at 20 ^{o}C (Symonds *et al.* 1986). This increase in heat production is achieved by increasing the provision and oxidation of metabolites by the tissues.

The increased concentration of NEFA on days 1,3,7 and 14 after shearing, and of 3-hydroxybutyrate on days 1 and 3 clearly indicated a

metabolic response by animals in both groups to shearing (Table 4.4, Figure 4.3). It also reflected the important role of these metabolites in providing energy to the tissues. These results are in accord with those of Astrup and Nedkvitne, 1988 and Symonds *et al.* 1988a who observed that NEFA concentration were elevated in pregnant ewes on days 4 and 10 after shearing though over the remaining seven weeks of pregnancy differences disappeared. Moreover, in the present experiment the NEFA and 3-hydroxybutyrate concentrations were significantly greater in the group shorn with the conventional comb than those of the group shorn with the cover comb. This indicated the energy requirements of the ewes shorn by the conventional method were higher than those of the ewes shorn with the cover comb and demonstrated that the adverse effect of shearing can be reduced by the use of the cover comb.

NEFA is an important source of energy (Aulie *et al.* 1971 and Symonds *et al.* 1986) released from triglycerides (triacylglycerols) present in the adipose tissues. Triglycerides are hydrolyzed in the adipose tissue by a hormone-sensitive lipase to glycerol and NEFA which are released into the blood stream. The NEFA are broken down in a number of tissues by beta-oxidation to acetyl CoA which enters the tricarboxylic acid (TCA) cycle and is oxidized to carbon dioxide and releasing energy (Metz and Van den Berg, 1977). Incomplete oxidation leads to the accumulation of 3-hydroxybutyrate and an increase in its concentration in the blood. Therefore, the change in NEFA and 3-hydroxybutyrate concentration in plasma after shearing reflects a mobilization of fat from the adipose tissue (Halliday *et al.* 1969; Aulie *et al.* 1971 and Russel, 1984).

Glucose concentration increased on days 1 and 3 after shearing in both groups in accord with Astrup and Nedkvitne (1988), even though in this experiment the increase was not significant. The reason may be due to differences between the studies in environmental temperature and nutrition. Thus, Astrup and Nedkvitne (1988) subjected their ewes to -1.7 ^{o}C and fed hay, grass silage and concentrate mixture, while in this experiment mean temperatures was higher (3.7 to 14 ^{o}C) and the ewes were fed only pasture.

Several mechanisms probably contribute to the increased glucose concentrations in blood of ewes subjected to a cold stress. Glucose synthesis from glycerol was probably stimulated because it has been shown that glycerol entry rate was 41 % higher in shorn pregnant sheep (Symonds, 1986), reflecting the mobilisation of triacylglycerols from the adipose tissues. However, if all the extra glycerol released into the circulation in the shorn ewe were converted to glycerol it would only account for an approximately 8 % increase in glucose synthesis. Therefore it has been suggested that catabolism of protein may be stimulated during cold exposure and gluconeogenic amino acids converted to glucose in the liver (Thompson *et al.* 1982; Astrup and Nedkvitne, 1988).

Declines in urea and creatinine concentration with time after shearing were found in both groups. The fall in urea concentration was similar to that reported by Astrup and Nedkvitne (1988) in ewes after shearing. The reason for the fall in urea and creatinine concentrations is not known especially since an increase in food intake after shearing

or increased gluconeogenesis from endogenous protein would be expected to increase the turnover of nitrogenous metabolites. In sheep selected for wool growth reduced plasma urea and creatinine concentrations, however, reflected an increased glomeruler filtration rate (Clark, 1987 and McCutcheon *et al.* 1987). Thus changes in the glomerular filtration rate in the kidney may have altered the circulating concentrations of urea and creatinine independent of any changes in their rates of synthesis.

In summary, as judged by the circulating concentrations of metabolites, the ewes shorn with the conventional comb were more severely stressed than those shorn with the cover comb. This difference is probably related to a difference between the groups in insulation. In the group shorn by the conventional shearing method less wool was left on the sheep than on those shorn by the cover method and even though the differences was small the extra wool would significantly reduce the amount of heat lost from the skin surface. Therefore, because more heat was lost by the conventional group, rectal temperatures fell more than those of the cover group even though the differences were not significant. In response to the cold stress fatty acids were mobilized from the adipose tissue to increase heat production and thus elevating plasma concentrations of NEFA and ketones.

.4. Wool growth

The ewes shorn by the conventional method produced 6 % less wool, s measured by the mid side patch, than the ewes shorn with the cover :omb by day 67 after shearing though the difference was statistically ıon significant. The wool growth to day 67 will be influenced by many :actors, for example, pre-lamb shearing methods, environmental temperature, season, feed intake, pregnancy and lactation and interactions between them. Therefore, large variation in the results would be expected. Nevertheless the group shorn with the conventional comb was subjected to a greater cold stress as indicated by the metabolite concentrations (see 5.3), so they might be expected to eat more to meet their demand for more energy. However, feed intake measured for the first 21 days (3 periods) of the 67 days after shearing clearly showed there were no differences in intake immediately after shearing. Therefore, the failure to measure differences wool grown in the short term after shearing is not surprising. Finally, although differences between the two groups in food intake and wool production were not significant it is probable that both these parameters increased following shearing. Thus, Wodzicka-Tomaszewska (1963); Corbett (1979); Williams *et al.* (1983); Hawker *et al.* (1984) and Oddy (1985) have shown that food intake of pregnant ewes is increased after shearing and that this leads to an increased wool growth.

Wool growth after shearing was greatest in the non-pregnant ewes and least in the ewes which reared twin lambs with growth in ewes

rearing single lambs intermediate between these two (Table 4.5). These results were similar to those reported by Corbett (1979) and Oddy (1985). It is probable that in the non-pregnant animal a greater proportion of energy intake was partitioned to wool growth, while in the lactating animals part of the intake was used for milk production leaving less available for wool growth. For example the clean wool production over the year was reduced by 5-8 % for ewes rearing a single lamb and the loss can be doubled in ewes rearing twins (Corbett, 1979). During lactation the total clean wool growth deficit increased as milk production increased, and for every litre of milk produced there was a deficit of 12 g clean wool (Oddy, 1985).

CONCLUSIONS

VI. CONCLUSIONS

Overall the effects of method of pre-lamb shearing on feed intake, rectal temperature, metabolic status, lamb birth weight and wool production in the present experiment leads to the following conclusions:

1. The method of pre-lamb shearing did not affect the food intake of pregnant ewes.

2. The method of pre-lamb shearing did not affect various measures of production including, the live weight of the ewes, the birth weight and growth rate of the lambs or wool growth of the ewes.

3. Ewes shorn by the conventional method were more severely cold stressed than the ewes shorn with the cover comb as indicated by the higher concentrations of NEFA and 3-hydroxybutyrate in the plasma of the former group after shearing.

4. Rectal temperature was a less sensitive measure of cold stress than the concentration of NEFA and 3-hydroxybutyrate in that the small difference between the groups in rectal temperature after shearing was not statistically significant.

5. Pre-lamb shearing with a cover comb reduces the severity of the cold stress on the ewe in comparison with the conventional method and in more severe conditions than experienced in this experiment may significantly reduce losses in production.

APPENDIX A

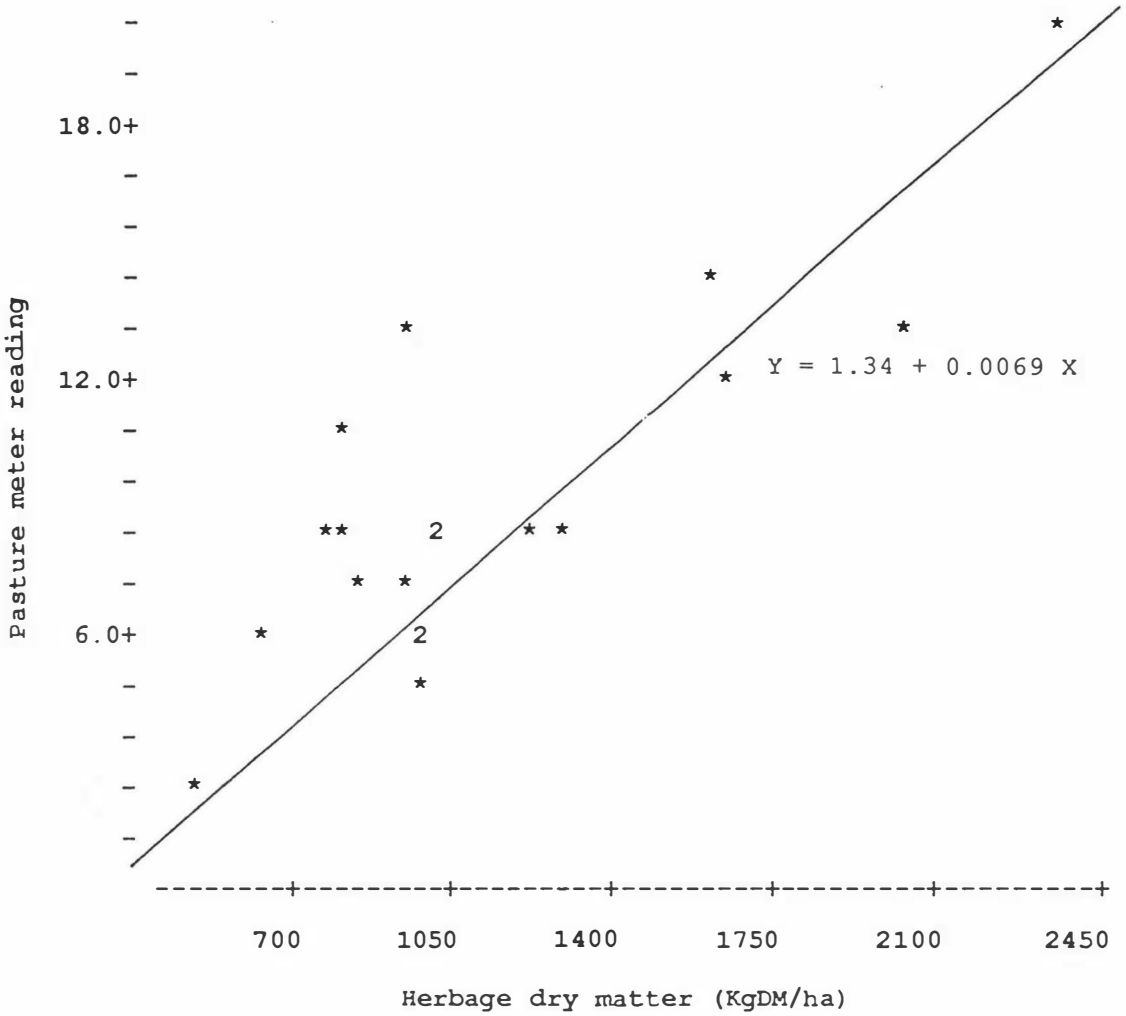

Figure 1. The relationship between herbage dry matter (KgDM/ha) and pasture meter reading

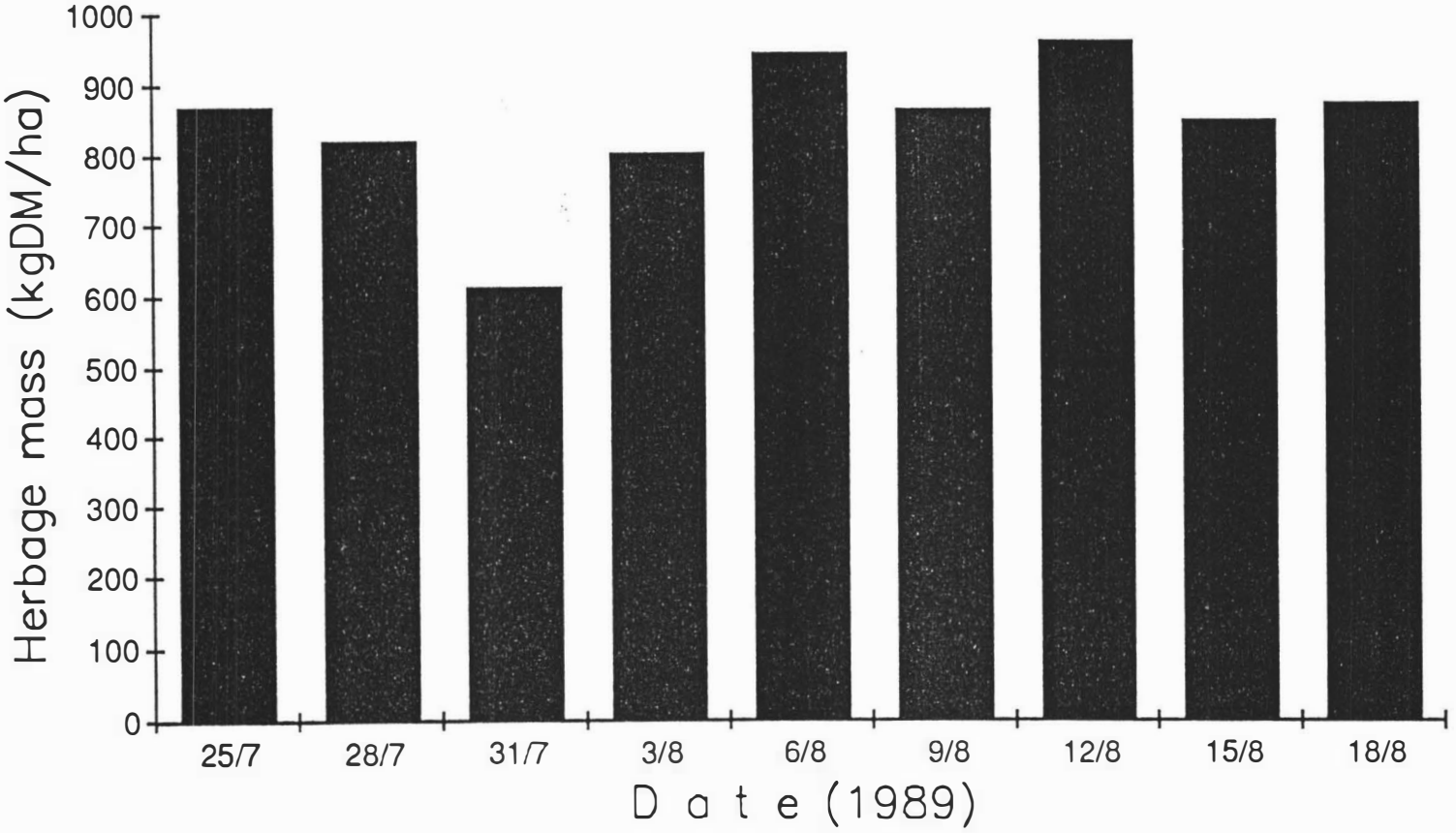

Figure 2. The herbage mass on the paddock which the ewes grazed over the experimental period

Table 1. The chemical composition and the *in vitro* digestibility of the pasture

	Periods		
	Week 1	Week 2	Week 3
Dry matter (%)	94.4	95.2	94.2
Crude protein (%) (Nx6.25)	20.6	19.4	18.1
Ash (%)	10.6	18.6	9.6
In vitro : DMD (%)	72.6	70.5	71.2
OMD (%)	77.6	77.8	76.6
DOMD (%)	69.2	65.0	68.6

Table 2. The mean and (range) for the daily maximum and minimum temperature, wind velocity, relative humidity (RH), rainfall, and sunshine over the first 14 days and the whole (67 days) of the experimental period

Period	Temperature[1]		Wind velocity[1]	RH[2]	Rainfall[2]	Sunshine[2]
	Max.	Min.				
(days)	(°C)	(°C)	km/h	(%)	(mm)	(h)
0-14	14.2	3.7	7.5	80.1	0	6.5
	(10.0-17.5)	(-2.5-11.0)	(0.70-42.5)	(71-92)	(0-0)	(2.2-9.6)
0-67	13.4	5.2	8.5	80.1	1.2	4.7
	(09.3-20.8)	(-2.5-14.0)	(0.61-46.8)	(67-97)	(0-15)	(0.0-9.8)

1) Recorded in the field

2) From DSIR records

REFERENCES

REFERENCES

Annison, E.F. (1960): Plasma non-esterified fatty acid in sheep. *Australian journal of agriculture research 11*: 58-64.

Arnold, G.W. (1970): Regulation of food intake in grazing animals. *In*: Physiology of digestion and metabolism in the ruminant. Edited by A.T. Phillipson. Oriel press, Newcastle, U.K.: 264-276.

Arnold, G.W. and M.L. Dudzinski (1967): Studies on the diet of the grazing animal. II. The effect of physiological status in ewes and pasture availability on herbage intake. *Australian journal of agricultural research 18* : 349-359.

Astrup, H.N. and J.J. Nedkvitne (1988): Changes in blood parameters in pregnant ewes after shearing. *Norwegian journal of agricultural sciences 2* : 39-44.

Aulie, A.; H.N. Astrup; J.J. Nedkvitne; and W. Velle (1971): Serum non-esterified fatty acids and plasma glycerol as indicators of fat mobilization in pregnant sheep subjected to cold stress. *Acta veterinary Scandinavia* 12 : 496-503.

Austin, A.R. and N.E. Young (1977): The effect of shearing pregnant ewes on lamb birth weight. *The veterinary record 18* : 527-529.

Baile, C.A. (1971): Control of feed intake and the fat depots. *Journal of dairy science 54 (4)*: 564-582.

Baile, C.A. and M.A. Della-Fera (1981): Nature of hunger and satiety control system in ruminants. *Journal of dairy science 64*: 1140-1152.

Baile, C.A. and J.M. Forbes (1974): Control of feed intake and regulation of energy balance in ruminants. *Physiological reviews 54*: 160-214.

Baile, C.A.; A.W. Mahoney and J. Mayer (1967a): Preliminary report on hypothalamic hyperphagia in ruminants. *Journal of dairy science 50 (11)*: 1851-1854.

Baile, C.A.; A.W. Mahoney and J. Mayer (1967b): Preliminary report on feeding activity and hypothalamic temperature in goats. *Journal of dairy science 50 (11)*: 1854-1856.

Baile, C.A.; A.W. Mahoney and J. Mayer (1968): Induction of hypothalamic aphagia and adipsia in goats. *Journal dairy science 51 (9)*: 1474-1477.

Baile, C.A and C.L. McLaughin (1987): Mechanism controlling feed intake in ruminants: A review. *Journal of animal science 64*: 915-922.

Baird, G.D. (1981): Lactation, pregnancy and metabolic disorder in the ruminant. *Proceedings of the nutrition society 40*: 115-120.

Baird, G.D.; J.G. Van Der Walt and E.N. Bergman (1983): Whole-body metabolism of glucose and lactate in productive sheep and cows. *British journal of nutrition 50* : 249-265.

Baumgard, B.R. (1970): Regulation of feed intake and energy balance. *In*: Physiology of digestion and metabolism in the ruminant. Edited by A.T. Phillipson. Oriel Press, Newcastle, U.K.: 235-253.

Bergman, E.N. (1973): Glucose metabolism in ruminants as related to hypoglycemia and ketosis. *Cornell veterinary 63*: 341-382.

Bergman, E.N.; D.J. Starr and S.S. Reulein (1968): Glycerol metabolism and gluconeogenesis in the normal and hypoglycaemic ketotic sheep. *American journal of physiology 215*: 874-880.

Bhattacharya, A. and M. Uwayjan (1975): Effect of high ambient temperature and low humidity on nutrient utilization and on some physiological responses in Awasi sheep fed different levels of roughage. *Journal of animal science 40*: 320-328.

Bigham, M.L. (1974): Effects of shearing interval on fleece weight and wool growth on a delineated midside patch. *New Zealand journal of agricultural research 17*: 407-410.

Bines, J.A. (1971): Metabolic and physiological control of food intake in ruminants. *Proceedings of the nutrition society 30*: 116-122.

Bines, J.A. (1979): Voluntary food intake . *In*: Feeding strategy for the high yielding dairy cow. Edited by W.F. Broster and H. Swan. Granada: 23-48.

Black, J.L.; G.E. Robards and R. Thomas (1973): Effects of protein and energy intakes on the wool growth of merino wethers. *Australian journal of agricultural research 24*: 399-412.

Blaxter, K.L. and F.W. Wainman (1964): The effect of increased air movement on the heat production and emission of steers. *Journal of agricultural science 62*: 207-214.

Bligh, J. (1973): Temperature regulation in mammals and other vertebrates. North Holland publ. co., Amsterdam.

Bowden, D.M. (1971): Non-esterified fatty acids and ketone bodies in blood as indicators of nutritional status in ruminants: A review. *Canadian journal of animal science 51*: 1-13.

Bowen, G. (1963): Wool away ! (The technique and art of shearing). Whitcombe and Tombs limited: 8-13.

Bremers, R.P.M.; P.F. Morgan; S.N. McCutcheon and R.W. Purchas (1988): Effect of plane of nutrition on energy and nitrogen retention and on plasma urea concentrations in Southdown ram hoggets from high and low backfat selection lines. *New Zealand journal of agricultural research 31*: 1-7.

Butler, B.M.; C.J. Hoogendoorn and M.A. Richardson (1987): Pasture quality and animal performance over late spring and summer. *Proceedings of the New Zealand society of animal production 47*: 31-33.

Campbell, J.W. (1973): Nitrogen excretion. *In*: Comparative animal physiology. Edited by C.L. Prosser. W.B. Saunders Company Philadelphia-London-Toronto: 280.

Carruthers, V.R. and A.M. Bryant (1983): Evaluation of the use of chromium oxide to estimate the feed intake of diary cows. *New Zealand journal of agricultural research 26*: 183-186.

Chaiyabutr, N.; A. Faulkner and M. Peaker (1982): Glucose metabolism in vivo in fed and 48 h starved goats during pregnancy and lactation. *British journal of nutrition 47*: 87-94.

Chandler, K.D.; B.J. Leury; A.R. Bird and A.W. Bell (1985): Effects of undernutrition and exercise during late pregnancy on uterine, fetal and uteroplacental metabolism in the ewe. *British journal of nutrition 53*: 625-635.

Chase, L.E. (1985): Dry matter intake-application problems in the field. *Proceedings of the Cornell nutrition conference*: 27-32.

Christopherson, R.J. (1976): Effects of prolonged cold and the outdoor winter environment on apparent digestibility in sheep and cattle. *Canadian journal of animal science 56*: 201-212.

Ciszuk, P. and J.E. Lindberg (1988): Responses in feed intake, digestibility and nitrogen retention in lactating dairy goats fed increasing amounts of urea and fish meal. *Acta agricultural Scandanavia 38*: 381-395.

Clark, C.M.; D.D.S. Mckenzie; S.N. McCutcheon and H.T. Blair (1989): Physiological responses to selection for greasy fleeceweight in Romney sheep. *New Zealand journal of agricultural research 32*: 29-36.

Cocimano, M.R.; and R.A. Leng (1966): Urea metabolism in sheep. *Proceedings of the Australian society of animal production 6*: 378-383.

Coop, I.P and K.R. (1963): Maintenance and lactation requirements of grazing sheep. *Proceedings of the New Zealand society of animal production 23*: 53-61.

Corbett, J.L. (1979): Variation in wool growth with physiological state. *In*: Physiological environmental limitations to wool growth. Edited by Black, J.L. and P.J. Reis. Proceedings of a national workshop. Leura, New South Wales, Australia. The University of New England publishing unit: 79-98.

Corbett,J.L. and E.P. Furnival (1976): Early weaning of grazing sheep sheep. 2. Performance of ewe. *Australian journal of experimental agriculture and animal husbandry 16*: 156-166

Costigan, P. and K.J. Ellis (1986): Analysis of faecal chromium derived from controlled release marker devices. *New Zealand journal of technology 3*: 89-92.

Dalton, D.C.; T.W. Knight and D.L. Johnson (1980): Lamb survival in sheep breeds on New Zealand hill country. *New Zealand journal of agricultural research 23*: 167-173.

Davey, A.W.F. (1973): The regulation of the voluntary intake of food by sheep. *Ph.D. thesis.* Massey university.

Davey, A.W.F. and C.W. Holmes (1977): The effects of shearing on the heat production and activity of sheep receiving dried grass or ground hay. *Animal production 24*: 355-361.

Davies, C.L. and D.E. Bauman (1974): General metabolism associated with the synthesis of milk. *In*: Lactation, volume II. Edited by B.L. Larson and V.R. Smith. Academic press. New York: 3-30.

Davies, P.J.; R.G. Johston and D.B. Ross (1971): The influence of energy intake on plasma levels of glucose, non esterified fatty acids and acetone in the pregnant ewe. *Journal of agricultural science, Cambridge* 77: 261-265.

Della-Fera, M.A. and C.A. Baile (1984): Control of feed intake in sheep. *Journal of animal science 59 (5)*: 1362-1368.

Dulphy, J.P.; B. Remond and M. Theriez (1980): Ingested behaviour and related activities in ruminants. *In*: Digestive physiology and metabolism in ruminants. Edited by Y. Ruckebusch and P. Thivend. MTP. press, Lancaster, U.K.: 103-122.

Early, D.F and A.A. McGowan (1979): Evaluation and calibration of an automated rising plate meter for estimating dry matter yield of pasture. *Australian journal of experimental agricultural and animal husbandry 19*: 337-343.

Ellis, K.J.; R.H. Laby and R.G. Burns (1981): Continuous controlled-release administration of chromic oxide to sheep. *Proceedings of the nutrition society of Australia 6*: 145.

Ellis, K.L. and B.R. Rodden (1987): Measuring faecal output of grazing ruminants using the captec chromic oxide controlled release capsule. *Paper 1X-14, 4 th AAAP animal science congress (Hamilton-New Zealand) program*: 54.

Elvidge, D.G. and I.E. Coop (1974): Effect of shearing on feed requirements of sheep. *New Zealand journal of experimental agriculture 2*: 397-402.

Farrell, D.J. and J.L. Corbett (1970): Fasting heat production of sheep at pasture before and after shearing. *Proceedings of the Australian society of animal production 8*: 267-271.

Farrel, D.J.; R.A. Leng and J.L. Corbett (1972): Undernutrition in grazing sheep. II. Calorimetric measurements on sheep taken from pasture. *Australian journal of agricultural research 23*: 499-509.

Faulkner A. (1983): Foetal and neonatal metabolism. *In*: Nutritional physiology of farm animals. Edited by J.A.F. Rook and P.C. Thomas. Longman. London and New York : 203-242.

Fenton, T.W and M. Fenton (1979): An improved procedure for the determination of chromic oxide in feed and faeces. *Canadian journal of animal science 59*: 631-634.

Fitzgerald, J.M.; D.C. Smeaton and K.T. Jagusch (1984): Fleece tenderness: the effect of nutrition, age and lambing status on pregnant Romney and Coopworth mixed-age ewes. *Proceedings of the New Zealand society of animal production 44*: 53-56.

Forbes, J.M. (1986): The voluntary food intake of farm animals. Butterworths. London.

Forbes, T.D.A. and J. Hodgson (1985): Comparative studies of the influence of sward conditions on the ingestive behaviour of cows and sheep. *Grass and Forages Sciences 40*: 69-77.

Fraser, T.J. (1982): High animal production from low herbage allowances. *Proceedings of the New Zealand society of animal production 42*: 177-178.

Gallagher, J.R. and M.K. Hill (1970): Growth and wool production of single and twin-born merino lambs reared on a high plane of nutrition. *Proceedings of the Australian society of animal production 8*: 144-148.

Gandar, L.W. (1965): Further results of second shear experiments-gaps in farmers' wool knowledge. Wool 4(3): 49-55

Geenty, K.G. and P.V. Rattray (1987): The energy requirements of grazing sheep and cattle. In: Livestock feeding on pasture. *New Zealand society of animal production, occasional publication no 10*: 39-53.

Goodwin, I.R. and V.J. Williams (1984): Renal control of plasma urea level in sheep: the diuretic effect of urea, potassium and sodium chloride. *Quarterly journal of experimental physiology 69*: 49-59.

Graham, N.McC.; F.W. Graham; K.L. Blaxter and D.G. Armstrong (1959): Environmental temperature, energy metabolism and heat regulation in sheep. I. Energy metabolism in closely clipped sheep. *Journal of agricultural science 52*: 13-40.

Graham, A.D. and G.D. Phillips (1981): Plasma glucose, lactate and free fatty acid responses to adrenaline in chronically warm-and cold-exposed sheep. *Canadian journal of animal science 61*: 919-924.

Guada, J.A.; J.J. Robinson and C. Fraser (1976): The effect of a reduction in food intake during late pregnancy on nitrogen

metabolism in ewes. *Journal of agricultural science, Cambridge 86*: 111-116.

Hadjipieris, G. and W. Holmes (1966): Studies on feed intake and feed utilization by sheep. 1. The voluntary feed intake of dry, pregnant and lactating ewes. *Journal of agricultural science 66*: 217-223.

Halliday, R.; A.R. Sykes; J. Slee; A.C. Field and A.J.F. Russel (1969): Cold exposure of southdown and welsh mountain sheep. 4. Changes in concentrations of free fatty acids, glucose, acetone, protein-bound iodine, protein and antibody in the blood. *Animal production 2(4)*: 479-491.

Harrison, F.A.; R.H. Laby and J.L. Mangan (1981): A slow-release marker capsule for studies of digestion in the sheep. *Journal of physiology London 319*: 1P.

Hawker, H. and S.F. Crosbie (1985): Effects of level of nutrition in winter and summer on the wool growth of Romney and Perendale ewes with a history of high or low winter wool growth. *Proceedings of the New Zealand society of animal production 45*: 225-228.

Hawker, H.; S.F. Crosbie and K.F. Thompson (1982): Effects of season and pasture allowance on the wool growth of Romney ewes. *Proceeding of New Zealand society of animal production 42*: 183-185.

Hawker, H.; S.F. Crosbie; K.F. Thompson and J.C Mcewan (1984): Effects of season on the wool growth response of Romney ewes to pasture allowance. *Animal production in Australia 15*: 380-383.

Hay, W.W.; J.W. Sparks; R.B. Wilkening; F.C. Battaglia and G. Meschia (1983): Partition of maternal glucose production between conceptus and maternal tissues in sheep. *American journal of physiology (Endocrinology and metabolism 8)*: E347-E350.

Henderson, A.E. (1965): How shearing affects the wool clip. *Sheep farming annual 1965*: 81-90.

Hodgson, J. (1977): Factors limiting herbage intake by the grazinng animal. *Proceedings of the international meeting on animal production from temperate grassland.* An Foras Taluntais. Dublin: 70-75.

Hodgson, J. (1982): Influence of sward characteristics on diet selection and herbage intake by the grazing animal. *In*: Nutritional limits to animal production from pastures. Edited by J.B. Hacker. Proceedings of an International symposium held at St Lucia, Queensland, Australia, Commonwealth agricultural bureau: 253-163

Hodgson, J. (1985): The control of herbage intake in the grazing ruminant. *Proceedings of the nutrition society 44*: 339-346.

Holmes, C.W. (1979): The effects of climatic factors on the productivity of farm animals. *Animal science department*. Massey university.

Holmes, C.W. and G.F. Wilson (1984): Milk production from pasture. Butterworths. Wellington.

Holmes, W. (1980): Grazing management. In: Grass: its production and utilization. Edited by W. Holmes. The British grassland society. Blackwell scientific publications: 125-173.

Holst, P.J.; I.D. Killeen and B.R. Cullis (1986): Nutrition of the pregnant ewe and its effect on gestation length, lamb birth weight and lamb survival. *Australian journal of agricultural research 37*: 647-655.

Hu, G.; McCutcheon, S.N.; Parker, W.J. and P.A. Walsh (1990): Blood metabolites levels in late pregnant ewes as indicators of their nutritional status. *New Zealand journal of agricultural research 33*: 63-68.

Ingram, D.L. and L.E. Mount (1975): Topics environmental physiology and medicine: Man and animals in hot environments. Springer-Verlag, Berlin, Heidelberg, New York: 6-7.

Johnson, K.G. (1971): Body temperature lability in sheep and goats during short-term exposures to heat and cold. *Journal of agricultural science, Cambridge* 77: 267- 272.

Joyce J.P.and K.L. Blaxter (1964): The effect of air movement, air temperature and infrared radiation on the energy requirements of sheep. *British journal of nutrition 18*: 5-27.

Judson, G.J. and R.A. Leng (1968): Effect of diet on glucose synthesis in sheep. *Proceedings of the Australian society of animal production*: 354-358.

Kleiber (1961): The fire of life. John wiley and sons inc, New York.

Kobt, A.R. and T.D. Lucky (1972): Markers in nutrition. *Nutrition abstract and reviews 42(3)*: 814-845.

Laby, R.H.; C.A. Graham; S.R. Edwards and B. Kautzner (1984): A controlled release intraruminal device for the administration of fecal dry-matter markers to the grazing ruminant. *Canadian journal of animal science 64 (Supplement)*: 337-338.

Leaver, J.D. (1961): Milk production from grazed temperate grassland. *Journal of dairy research 52*: 313-344.

Leaver, J.D. (1985): Milk production from grazed temperate grassland. *Journal of dairy research 52*: 313-344.

Lee, J.; M.T. Fisher and B. Mare (1986): Comparison of techniques for chromium sesquioxide analysis in marker studies. *Journal of science food agriculture 37*: 366-372.

L'Huillier, P.J.; D.P. Poppi and T.J. Fraser (1984): Influence of green leaf distribution on diet selection by sheep and the implications for animal performance. *Proceedings of the New Zealand society of animal production 44*: 105-107

Lindsay, D.B. (1970): Carbohydrate metabolism in ruminants. *In*: Physiology of digestion and metabolism in the ruminant. Edited by A.T. Phillipson. Oriel press. Newcastle:438-451.

Linzell, J.L. (1974): Mammary blood flow and substrate uptake. *In*: Lactation, volume I. Edited by B.L. Larson and V.R. Smith. Academic press. New York: 143-225.

Livingston, P.J. and W.J. Parker (1985): Comparing shearing policies. Riverside farm. Publication no. 10. Massey university: 1-42.

Mackenzie, D.D.S.; J.P. Bridges and M.F. Scott (1989): Protocol for assay of β-hydroxybutyrate. Animal science department. Massey university.

Marshall, P.T. and G.M. Hughes (1980): Physiology of mammals and other vertebrates. Cambridge university press: 179-181.

Maund, B.A. (1980): Shearing ewes at housing. *Animal production 30* (abstract): 481.

McCutcheon, S.N; D.D.S. Mackenzie and H.T. Blair (1987): Nitrogen metabolism and plasma urea concentrations in fleeceweight-selected and control Romney rams. *Australian journal of agricultural research 38*: 917-926.

McDowell, G.H. (1983): Hormonal control of glucose homestasis in ruminants. *Proceedings of the nutrition society 42*: 149-167.

McInnes, P and R.P. Moir (1970): Urinary nitrogen excretion of sheep fed nitrogen-free diets. *Proceedings of the Australian society of animal production*: 29-33.

McIntyre, K.H. (1970): The effects of increased nitrogen intakes on plasma urea nitrogen and rumen ammonia levels in sheep. *Australian journal of agricultural research 2*: 501-507.

McIntyre, K.H. and V.J. Williams (1970): The effects of intravenous urea infusions on nitrogen metabolism in sheep. *Australian journal of agricultural research 21*: 95-105.

McMillan, W.H. and T.W. Knight (1982): Shearing and time of joining effects on reproduction in two-tooth ewes. *Proceedings of the New Zealand society of animal producton 42*: 45-46.

McNiven, M.A. (1984): Glucose metabolism in fat and thin adult sheep. *Canadian journal of animal science 64*: 825-832.

Meijs, J.A. (1981): Herbage intake by grazing dairy cows. Agricultural research report 909. Centre for agricultural publishing and documentation. Wageningen. Netherlands.

Mellor, D.J.; J.S. Slater and I.C. Matheson (1975): Effect of changes in ambient temperatures on maternal plasma and allantoic fluid from chronically catheterised ewes during the last two months of pregnancy. *Research in veterinary science 18*: 219-221

Metz, S.H.M. and S.G. van den Bergh (1977): Regulation of fat mobilization in adipose tissue of dairy cows in the period around parturition. *Netherlands journal of agriculture science 25*: 198-211

Miettinen, H. and P. Huhtanen(1989): The concentration of blood metabolites and the relations between blood parameters, fatty acid composition of milk and estimated ME-balance in dairy cow given grass silage and libitum with five different carbohydrate supplements. *Acta agricultural scandinavia 39*: 319-330.

Ministry of transport - New Zealand meteorological service (1989). Daily climatological observations. Grasslands division DSIR.

Minson, D.J. (1982): Effects of chemical and physical composition on herbage eaten upon intake. *In*: Nutritional limits to animal production from pastures. Edited by H.B. Hacker. Proceedings of an international symposium. Santa Lucia: 167-182.

Mount, L.E. (1979): Adaptation to thermal environment: man and his productive animals. Edward Arnold. London.

Nedkvitne, J.J. (1972): Effect of shearing before and after lambing. *Acta agricultural Scandinavia 22*: 97-145.

Nolan, J.V. and R.A. Leng (1968): Contributions of protein to glucose synthesis in pregnant and non-pregnant sheep. *Proceedings of animal production* 348-353.

NRC (1981): Effect of environment on nutrient requirements of domestic animals. National academy press. Washington D.C.: 85-95.

Oddy, V.H. (1985): Wool growth of pregnant and lactating Merino ewes. *Journal of agricultural science, Cambridge 105*: 613-622.

Owen, J.B. and J.W. Ingleton (1963): A study of food intake and production in grazing ewes. II. The interrelationships between food intake and productive output. *Journal of agricultural science 61*: 329-340.

Palmquist, D.L.; C.L. Davis, ; R.E. Brown and D.S. Sachan (1969): Availability and metabolism of various substrates in ruminants. V. Entry rate into the body and incorporation into milk fat of D(-) beta hydroxybutyrate. *Journal of dairy science 52*: 633-638.

Parker, W.J. (1984): The effects of differential set stocking rates on the performance of single and twin-bearing ewes during the lambing to weaning period. Pregnancy diagnosis and its benefits. Massey farm series no 2. Massey university: 27-40.

Parker, W.J.; S.N. McCutcheon and D.H. Carr (1989): Effect of herbage type and level of intake on the release of chromic oxide from intraruminal controlled release capsules in sheep. *New Zealand journal of agricultural research 32*: 537-546.

Patterson, D.S.P. (1963): Some observasions on the estimation of non-esterified fatty acid concentrations in cow and sheep plasma. *Research in veterinary science 4*: 230-237.

Patterson, D.S.P.; K.N. Burn; N.F. Cunningham; C.N. Hebert and N. Saba (1964). Plasma concentrations of glucose and non-esterified fatty acid (NEFA) in the pregnant and lactating ewe and the effect of dietary restriction. *Journal of agricultural science 62*: 253-262.

Peart, J.N. (1967): The effect of different levels of nutrition during late pregnancy on the subsequent milk production of Blackface ewes and on the growth of their lambs. *Journal agricultural science, Cambridge 68*: 365-371.

Pethick, D.W.; D.B. Lindsay; P.J. Baarker and A.J. Northrop (1983): The metabolism of circulating non-esterified fatty acids by the whole animal, hind-limb muscle and uterus of pregnant ewes. *British journal of nutrition 49*: 129-143.

Pigden, W.J. and G.J. Brisson (1956): Effect of frequency of administration of chromic oxide on its faecal excretion pattern by grazing wethers. *Canadian journal of animal science 361*: 146-155.

Poppi, D.P.; T.P. Hughes and P.J. L'Huillier (1987): Intake of pasture by grazing ruminants. *In*: Livestock feeding on pasture. Edited by A.M. Nichol. *New Zealand society of animal production.* Occasional publication no. 10: 55-63.

Rattray, P.V. and D.A. Clark (1984): Factors affecting the intake of pasture. *New Zealand of agricultural science 18*: 141-146.

Rattray, P.V.; K.F. Thompson; H. Hawker and R.M.W. Sumner (1987): Pasture for sheep production. *In*: Livestock feeding on pasture. Edited by A.M. Nichol. *New Zealand society of animal production*. Occasional publication no 10: 89-108.

Raymond, W.F and D.J. Minson (1955): The use of chromic oxide for estimating the faecal production of grazing animals. *Journal of British grassland society 10*: 282-296.

Richardson, C. (1972): Pregnancy diagnosis in the ewe : A review. *The veterinary record, March*: 264-274.

Robinson, J.J. (1986): Changes in body composition during pregnancy and lactation. *Proceedings of the nutrition society 45*: 71-80.

Robinson, J.J.; C. Fraser and C. Bennett (1971): An assessment of the energy requirements of the pregnant ewe using plasma free fatty acid concentrations. *Journal of agricultural science, Cambridge* 77: 141-145.

Roughan, P.G. and R. Holland (1977): Predicting in vivo digestibilities of herbages by exhaustive enzymic hydrolysis of cell walls. *Journal of science and food agriculture 28*: 1057-1064.

Russel, A.J.F.; R.H. Armstrong and I.R. White (1985): Studies on the shearing of housed pregnant ewes. *Animal production 40*: 47-53.

Russel, A.J.F; J.M. Doney and R.L. Reid (1967a): The use of biochemical parameters in controlling nutritional state in pregnant ewes, and the effect of undernourishment during pregnancy on lamb birth-weight. *Journal of agricultural science, Cambridge 68*: 351-358.

Russel, A.J.F.; J.M. Doney and R.L. Reid (1967): Energy requirments of the pregnant ewe. *Journal of agricultural science, Cambridge 68*: 359-363.

SAS (1988): Statistic user's guide. Release 6.03 edition. SAS institute inc., Cary. U.S.A.

Scales, G.H.; R.N. Burton and R.A. Moss (1986): Lamb mortality, birthweight, and nutrition in late pregnancy. *New Zealand Journal of agricultural research 29*: 75-82.

Schultz, L.H. (1974): Ketosis. *In*: Lactation, volume II. Edited by B.L. Larson and V.R. Smith. Academic press. New York: 318-354.

Scott, M.F. (1989): Personal communication. Animal science department, Massey university.

Schultz, L.H. (1974): Ketosis. *In*: Lactation, volume II. Edited by B.L. Larson and V.R. Smith. Academic press. New York: 318-354

Smeaton, D.C.; R.M.W. Sumner; T.W. Knight and T.K. Wadams (1983): Effects of time of weaning, psture allowance, and shearingg time on ewe and lamb liveweight, wool growth, and subsequent ovulation rate of the ewe. *New Zealand journal of experimental agriculture 11*: 41-45.

Smith, M.E. (1980): A review of effects of shearing on sheep production. *Proceedings of the New Zealand society of animal production 40*: 215-220.

Soderquist H.G. and K.L. Knox (1967): Temperature-energy relationships in fattening lambs. *Journal of animal science 26* (abstract): 930.

Stainer, M.W.; L.E. Mount and J. Bligh (1984): Energy balance and temperature regulation. Cambridge university press.

Steel, J.W. and R.A. Leng (1973): Effects of plane of nutrition and pregnancy on gluconeogenesis in sheèp. *British journal of nutrition 30*: 451-473.

Steel, R.G.D. and J.H. Torrie (1987): Principles and procedures of statistics, a biometrical approach. Second edition. International editions. McGraw Hill book company.

Story, L.F. (1955): Effect of shearing time on wool. 1. Introduction. *New Zealand journal of science and technology*: 267-273.

Story, L.F. and D.A. Ross (1960): Effect of shearing on wool VI. The rate of growth of wool and its relation to time of shearing. *New Zealand of agricultural research 3*: 113-124.

Stott, A.W. and J. Slee (1985): The effect of environmental temperature during pregnancy on thermoregulation in the newborn lamb. *Animal production 41*: 341-347.

Sumner, R.M.W. (1983): Effect of feeding and season on fleece on characteristics of Cheviot, Drysdale and Romney hogget wool. *Proceedings of the New Zealand society of animal production 43*: 79-82.

Sumner, R.M.W. (1984): Effects of shearing on meat and wool production from lambs reared on hill country. *Proceedings of the New Zealand society of animal production 44*: 45-48.

Sumner, R.M.W. (1986): Implications of objective measurement for sheep management. *Proceedings of the New Zealand society of animal production 46*: 198-200.

Sumner, R.M.W. and D. Armstrong (1987): Effect of different shearing policies on sheep production in Northland. *Proceedings of the New Zealand society of animal production 47*: 107-110.

Sumner, R.M.W.; M.L. Bigham; T.W. Knight and W.H. McMillan (1982): Shearing-its effects on production. *Proceedings of the Ruakura farmer's conference*: 31-34.

Sumner, R.M.W. and L.D. Wiiloughby (1985): Effect of post-weaning and post-mating/post-weaning shearing on ewe performance. *Proceedings of the New Zealand society of animal production 45*: 221-224.

Sumner, R.M.W. and L.D. Willoughby (1988): Effect of shearing once-yearly in October or twice-yearly in February and October on ewe performance. *Proceedings of the New Zealand society of animal production 48*: 213-217.

Symonds, M.E.; M.J. Bryant and M.A. Lomax (1985): The effect of shearing on plasma glucose, free fatty acid, growth hormone and insulin concentrations in the pregnant ewe. *Proceedings of the nutrition society 44* (abstract): 136.

Symonds, M.E.; M.J. Bryant and M.A. Lomax (1986): The effect of shearing on the energy metabolism of the pregnant ewe. *British journal of nutrition 56*: 635-643.

Symonds, M.E.; M.J. Bryant and M.A. Lomax (1988a): Metabolic adaptation during pregnancy in winter-shorn sheep. *Journal of agricultural science, Cambridge 111*: 137-145.

Symonds, M.E.; M.J. Bryant; D.A.L. Shepherd and M.A. Lomax (1988): Glucose metabolism in shorn and unshorn pregnant sheep. *British journal of nutrition 60*: 249-263.

Symonds, M.E. and M.A. Lomax (1989): Effect of short term intravenous infusion of noradrenaline on energy metabolism in shorn and unshorn pregnant sheep. *Research in veterinary science 46*: 58-61.

Ternouth, J.H. and A.W. Beattie (1970): A note on the voluntary food consumption and the sodium-potassium ratio of sheep after shearing. *Animal production 12*: 343-346.

Thomsen, L.V. (1971): The discovery and developments of shearing techniques. Hamilton. New Zealand: 5-16.

Thompson, G.E. (1983): The intake of milk by suckled, newborn lambs and the effects of twinning and cold exposure. *British journal of nutrition 50*: 151-156.

Thompson, G.E.; J.M. Bassett; D.E. Samson and J. Slee (1982): The effects of cold exposure of pregnant sheep on foetal plasma nutrients, hormones and birth weight. *British journal of nutrition 48*: 59-64.

Thornton, R.F. (1970): Factors affecting the urinary excretion of urea nitrogen in cattle. II. The plasma urea nitrogen concentration. *Australian journal of agricultural research 21*: 145-152.

Thornton, R.F. and D.J. Minson (1973): The relationsheep between apparent retention time in the rumen, voluntary intake, and apparent digestibility of legume and grass diets in sheep. *Australian journal of agricultural research 24*: 889-898.

Torrell, D.T. (1954): An esophageal fistula for animal nutrition studies. *Journal of animal science 13*: 878-884.

Tsuda, T.; K. Ambo; Y. Shoji; M. Fujita and K. Sunagawa (1984): Distribution of energy source expenditure in warm- and cold-exposed sheep. *Canadian journal af animal science 64 (supplement)*: 265-266.

Van der Walt, J.G.; G.D. Baird and E.N. Bergman (1983): Tissue glucose and lactate metabolism and interconversions in pregnant and lactating sheep. *British journal of nutrition 50*: 267-280.

Van Soest (1982): Nutritional ecology of the ruminant. O and B. Books inc., Carvallis, Oregon.

Vernon, R.G.; R.A. Clegg and D.J. Flint (1981): Metabolism of sheep adipose tissue during pregnancy and lactation (adaptation and regulation). *Biochemical journal 200*: 307-314.

Webster, A.J.F. and K.L. Blaxter (1966): The thermal regulation of 2 breeds of sheep exposed to air temperatures below freezing point. *Research in veterinary science* 7: 466-479.

Webster, A.J.F.; A.M. Hicks and F.L. Hays (1969): Cold climate and cold temperature induced changes in the heat production and thermal insulation of sheep. *Canadian journal of physiology and pharmacology 47(6)*: 553-562.

Webster, M.E.D. and J.J. Lynch (1966): Some physiological and behavioral consequences of shearing. *Procedings of the Australian society of animal production 6*: 234-239.

Weston, R.H. (1982): Animal factors affecting feed intake. *In*: Nutritional limits to animal production from pastures. Edited by J.B. Hacker. Proceedings of an International symposium. Santa Lucia. Commonwealth agricultural bureau: 183-198.

Weston, R.H. and J.P. Hogan (1968): Rumen ammonia in relation to characteristics of the diet and parameters of nitrogen metabolism. *Proceedings of the Australian society of animal production 8*: 359-363.

Whatter, R.J. and E.M. Evans (1979): Evaluation of sward sampling technique for estimating herbage intake by grazing sheep. *Grass and forage science 34*: 37-44.

Wheeler, J.L.; T.F. Reardon and L.J. Lambourne (1963): The effect of pasture avalability and shearing stress on herbage intake of grazing sheep. *Australian journal of agricultural research 14*: 364-372

Williams, A.J.; R.N. Tyrrell and A.R. Gilmour (1978): Effects on wool production during pregnancy and lactation of twice daily abomasal supplementation with casein or methionine and cystine. *Australian journal of experimental agriculture and animal husbandry 18*: 52-57.

Williamson, D.H. (1981): Mechanisms for the regulation of ketogenesis. *Proceedings of the nutrition society 40*: 93-98.

Wilson, S.; J.C. MacRae and P.J. Buttery (1983): Glucose production and utilization in non pregnant, pregnant and lactating ewes. *British journal of nutrition 50*: 303-316.

Wodzicka-Tomaszewska, M. (1963). The effect of shearing on sheep. *Proceedings of the Ruakura farmers' conference 13*: 28-39.