EFFECT OF ANIMAL TYPE OR TREATMENT ON THE EFFICIENCY OF LEAN MEAT PRODUCTION AND THE FATTY ACID COMPOSITION OF MEAT

THESIS SUBMITTED FOR THE DEGREE OF

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BY

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STATEMENT

I certify that this thesis contains no material which has been accepted for the award of any other degree or diploma in any University and that, to the best of my knowledge and belief, the thesis contains no material previously published or written by another person, except when due reference is made in the text.

DEDICATION

I WISH TO DEDICATE THIS WORK TO

A Mamam, a Papa, a Dene et a tous ceux qui me sont chers, je dedis ce modeste ouvrage

(To my Mother, Father, Dene and all those that are dear to me, I dedicate this modest work

SUMMARY

The consumption of saturated fat is known to be related to the incidence of coronary heart disease in humans. Part of the daily intake of fat by Australians arises from the consumption of red meat from sheep and cattle, but it could be reduced by producing leaner animals than those raised at present. In addition to the advantages of human health, there may be agricultural advantages also in terms of efficiency of production.

The study reported in the thesis examines:

(a) the effect of various breed types (x4) on the growth, body composition (fat content), feed intake and efficiency of conversion of feed to live weight and lean body of grazing sheep.

(b) the effect of androgenic and androgenic plus oestrogenic agents on the growth and body composition of sheep grazing or pen fed roughage or oil seed diets.

(c) the effect of the consumption of lean meat or meat with a modified fatty acid composition on the plasma lipids of other experimental animals.

It was necessary to employ and validate a number of methods and techniques in the study and to analyse a number of markers or metabolites in determining body pool, rates of digesta flow and tissue concentrations. These included:

(a) tritiated water space and calculation of body fat;
(b) azeotropic distillation of hydrogen isotopes;
(c) B-counting of isotopes;
(d) field use of chromic oxide slow release capsules (SRC);
(e) validation of use of SRCs in pen experiments;
(f) analysis of chromium by atomic absorption spectrometry;
(g) muscle biopsy of lambs by needle technique;
(h) thin layer and gas liquid chromatography of muscle lipids.

Following an introduction, the thesis presents a literature review which considers the background of the methods and findings of previous studies carried out on growth, body composition, feed intake of grazing animals, the use of anabolic agents, fatty acid composition of ruminants fats and the effect of saturated fat on human health. The

results are presented in three chapters, each with its own discussion. A general discussion follows.

The experiments carried out in the present study demonstrated a number of points. They were:

(i) The lamb breeds used showed differences in growth rate and body composition under field conditions.

(ii) The most common lamb used in meat production in Australia (Dorset cross breds) deposited fat at an earlier age than the other breeds, while Suffolk cross breds produced the most lean meat.

(iii) The practice of crossing British breeds with common wool producing Merinos lessens the amount of fat in the carcass by slowing down by body growth rate, not by lessening <u>per se</u> fat content at the same body weight.

(iv) Anabolic agents altered the natural composition of a particular breed; an oestrogenic agent implanted in wethers increased growth while an oestrogenic plus androgenic agent increased growth also but lessened fat deposition.

(v) Meat from animals of different fat content when incorporated into an omnivore diet, brought about cholesterol levels that were related to fat intake but were unaffected by meat intake.

(vi) When lambs were fed oil seed that altered their structural lipid to a different fatty acid type, an additional decrease in omnivore cholesterol occurred.

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CHAPTER 1. INTRODUCTION

The consumption of meat from sheep and cattle is of concern in the area of public health because of the large proportion of saturated fats in, or associated with ruminant meat (Crawford 1975). This results from the fact that the consumption of saturated fat leads to a rise in plasma cholesterol which is associated with high incidence of coronary heart disease (CHD) in western society (Keys 1970). For this reason it would be wise to lessen saturated fat consumption by lessening the amount of fat deposited in red meat livestock.

The rate of growth, the relative proportions of the major components (fat, protein, water and minerals) and to some degree the composition of the tissues are affected by the genetic background of animals and their environment (McCance 1977). Some animals are born to be small while others to be large even within a species, although a potentially large animal's growth can be modified by the amount and quality of the food it eats.

The proportion of some components of the body, for example fat, alter with age, although differences commence quite early in life (Searle et al 1972). This difference in composition alters the rate at which nutrients are utilised in the animal as a whole, or with respect to meat as a food, the efficiency at which lean meat is produced. In addition species differ in the amount of fat deposited and the number of adipocytes (fat cells) in their bodies (Searle 1977). The nature and the composition of adipose tissue or other lipid varies also, storage fats comprising mainly triglyceride of saturated fatty acids, whereas structural fats of cellular membranes comprised of phospholipids contain a degree of polyunsaturated fatty acids (Sinclair et al 1982).

A study of the efficiency of animal or meat production therefore requires measurements to be made of the growth of the whole body and the body components preferably without destruction of the animal. In addition changes in body development need to be made relative to the intake of nutrients. In the field this presents problems although some indirect techniques permit estimation of feed consumption. Just how large an effect animal type or diet have on the composition of the fats in animals, or humans for that matter, is not fully understood. The study reported here is aimed at elucidating some of the effects of the variables mentioned above, particularly with respect to lean meat production.

CHAPTER 2. REVIEW OF THE LITERATURE

2.1 PRIME LAMB PRODUCTION

2.1.1 Introduction

Sheep meat is an important component of the Australian livestock and meat industries, although its contribution to Australian red meat production has fluctuated over the years. Environmental pressures such as drought limit production while international market demands dictate the outcome of the industry. For instance in the early 1970's depressed wool prices and prolonged drought conditions in most Australian states resulted in heavy sheep slaughterings which brought about a major decline in the national flock.

Over the last 60 years two major expansionary phases were observed in the prime lamb industry:

(a) Phase (i) - 1920-1945

In those 25 years the prime lamb production trebled to a yearly average of 150k tonnes.

(b) Phase (ii) - 1970-1980

The annual prime lamb production averaged 250k tonnes which was almost 140% higher than the pre-1940 productions.

The rapid growth of the industry was influenced by the large scale expansion of improved pastures over the 1950's. The state of Victoria registered 1.27 million ha of improved pastures while in 1959 the improved pastures amounted to a total of 4.08 million ha. Also the extensive pasture improvement in high rainfall and wheat-sheep zones allowed the raising of prime (fat) lambs for market in areas where previously only wool production was carried out (Vere and Griffith 1984).

Despite its remarkable growth rate, the prime lamb industry witnessed some set-backs such as substantial reduction in the lamb export trade to the United Kingdom which prior 1940, totalled far over 60 per cent of annual lamb production. Other factors which contribute to the slow down of the prime lamb industry are its strongly seasonal nature which effects prices and producers returns; and the substitution of other meats for lamb at the retail level. Hopkins and

Congram (1985), from a lamb consumer survey, declared that overfatness was the major problem limiting the consumption of lamb. The public awareness in reducing fat intake has contributed to a drastic reduction of lamb meat consumption.

2.1.2 Production

Prime lamb production is a specialised activity which requires large pasture and management inputs. Generally prime lamb production is not run as a sole enterprise on a farm, but is undertaken in conjunction with other rural practices such as cereal cropping, wool growing, beef or dairy production. Prime lamb production has been seen as a new and valuable source of income by farmers (Tribe *et al* 1966).

2.1.2.1 Production Systems

The qualities required in the dam for meat production are high prolificacy, good mothering ability, high milk production and satisfactory wool production. In order to attain this type of breeding ewe, the following method has been adopted: cull or draft ewes from merino breeds are crossed with long-wool rams to produce half-bred (first cross) ewes. The male lambs from the first cross may be sold as lamb or mutton,

while the ewe-lambs are then joined to British breed short wool wool rams to produce second-cross prime lambs (Coleman 1939).

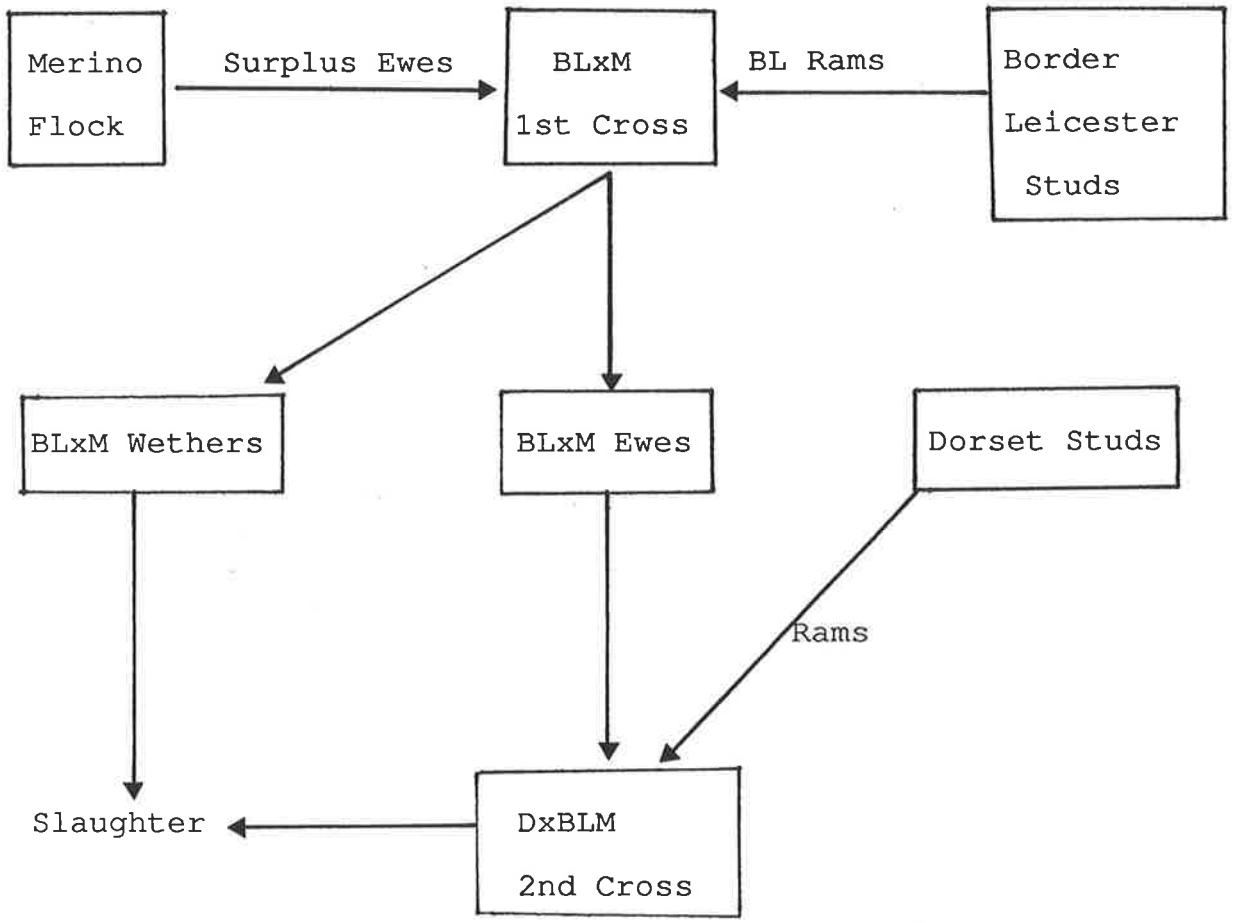
The Australian prime lamb production is a two-tiered process.

The prime-lamb industry is based on the Merino due to the fact that the breed dominates the wool industry and is readily available in large numbers. In the early days of the prime (fat) lamb production the industry was acknowledged as a complementary farming operation that under no circumstances would compete or interfere with the wool industry (Coleman 1939). In other words fat lamb industry was a "by-product" of the wool industry.

In New South Wales and Victoria where more than 75% of lambs are slaughtered, the industry relies largely on the Merino (M), Border Leicester (B.L.) and Dorset (D) breeds.

The Merino ewes are joined to Border Leicester rams to produce the first cross lambs. The wether lambs are slaughtered and the ewe lambs are sold either for slaughter or as prime lamb mothers. The BLxM ewes are joined to Dorset rams (short wool breed) and the progeny are slaughtered as prime lambs (Fogarty 1983).

Structure of the Prime Lamb Industry (Fogarty 1985)



However in South Australia and Western Australia in the cereal belt, the large-framed S.A. Merino is the main breed ewe. The short wool British breeds such as Dorset, Suffolk and Southdown are preferred as sires for the first crossing, because they produce big framed, rapidly maturing early lambs which can withstand a check to growth and recover when pasture conditions improve (Jefferies 1984).

But breeders in high rainfall areas claim that the Romney Merino cross has a more robust constitution and is therefore more resistant to disease and is better adapted to intensive methods of farming. However Romney/Merino first cross has not proved to be as productive as the Border Leicester cross. They are usually run as dual-purpose sheep for carpet wool (due to genetic mutations) and as prime lambs (Cannon et al 1973).

The current crossbreeding structure has developed over the last 60 years. It caters for efficient use of breed and land resources and provides an integral adaptability for the prime lamb producer.

Lambs for the meat market should be fast growing not overfat and thickset. In order to fulfil these criteria, the prime lamb breeder is required to cross early maturing sires with prolific, large-bodied good milking ewes, and to provide adequate feeding to ensure the ewes to lamb in good condition and to rear their lambs to a marketable weight without a check in their growth (Tribe et al 1966). Finally, crossbreeding combines the advantages of different breeds and also the progeny issued from it shows hybrid vigour which means that it may grow faster and convert its food into meat more efficiently than the pure bred progeny of either parent.

2.2 GROWTH OF SHEEP

2.2.1 Introduction

In general, growth in animals is defined as an increase in weight until mature size is reached, while changes in body shape, conformation and various functions and faculties are part of development (Hammond 1940).

These two concepts are closely related, thus any increase in size will incontestably involve a change in form. Growth is defined as: the change of size, live weight or biomass with time or some other variable. Parks (1982) described an animal as "a mobile, self-feeding well balanced macro-unit that generates microcatalistic chemical reactions in order to transform the energy and matter of the feed (input chemicals) into energy to be stored as live weight, compiled as products such as wool, milk, eggs or young and dissipated to the environment as work or heat".

Even though the growth of animals is changeable, the body mass of the individuals and populations of animals follows a defined course as they grow or age. The pattern of growth in various species is similar; the growth curve is known as the S-shape or Sigmoid Curve (Hammond 1940).

2.2.2 Growth Curve

The abscissa in such plots is time expressed in minutes, days, months or years depending on the organism studied. The ordinate is a measure of growth of a given living organism or any of its parts and, under optimal conditions, all show exactly the S-shaped growth curve. The growth curve is sectioned to three parts or phases (Sussman 1960).

2.2.2.1 Lag Phase

This initial phase is a period of rapid protoplasmic growth and a preparation for the cell division. Also it is the time of synthesis of enzymes and other macro molecules (such as amino acids, sugars, fatty acids, vitamins) to ensure cell growth. This phase is relatively slow, it is also identified as the preparation of growth.

2.2.2.2 Exponential Phase

This phase is also known as the logarithmic phase. It is the stage of active growth, it proceeds at an increasing rate with time for a while (until the inflection of the curve is reached).

2.2.2.3 Stationary Phase

It is the period at which growth ceases and the organism or the animal enters the maturity phase.

From an economic point of view, the time of inflection of the growth curve is important since the amount of food required to maintain the animal increases proportionately to its size. Feed consumption (relative to body wieght) lessens with decreasing growth rate as maturity is reached (Hammond et al 1971).

2.2.3 Growth Principles

Growth is due partly to cell multiplication, partly to increase in cell size and partly to the deposition of extra-cellular connective tissues. In 1962 Enesco and LeBlond established the fundamental principles of cellular growth. They are three and as follows:

(a) Total organ D.N.A. reflects total organ cell number: D.N.A. (deoxyribonucleic acid) is mainly localised within the nucleus of the cell. Also it is believed to be present in an amount characteristic of each species according to the ploidy (number of sets of chomosomes) of the cell.

Thus, every human diploid cell is likely to contain the same amount of D.N.A. (expressed in picograms) as every other human diploid cell. It is known, that the quantity of D.N.A. in picograms (a constant) for the human is 6.0 picograms per diploid cell. Thus the number of cells present in any organ can be estimated by analysing the organ for its D.N.A. content and dividing by the constant (i.e. 6.0 picograms).

(b) Weight/D.N.A. or Protein/D.N.A. refelcts "average" cell size: the organ or tissue by being weighed or analysed for total protein content will allow to assess the "average" cell size (protein content per cell). The "average" cell size is obtained by simply dividing the total protein content by the number of cells.

(c) R.N.A./D.N.A. or Lipid/D.N.A. reflects "average" quantity or R.N.A. or Lipid per cell: (R.N.A. is the Ribonucleic acid which is an intracellular substance). To establish the average quantity of any intracellular substance, (such as R.N.A., Lipid) would mean to divide the total organ content of the given intracellular substance by the number of cells.

Growth can be observed as an increase in cell number or hyperplasia and as an increase in cell size or hypertrophy (Winick 1978).

In all organs, growth is induced firstly by cell division then followed by an increase in cell size. In the early stages of development cell division is very rapid, for example, the human's kidneys by the 14 weeks' gestation contain over 1 mg of D.N.A. or the equivalent of 2000 million cells (Widdowson 1980).

Skeletal muscle is the most important lean tissue of the body. Furthermore, after birth its composition changes more than any other soft tissue, but the number and size of muscle cells cannot be calculated from the D.N.A. and protein, because muscle fibres are multinucleate (Goldspink 1977). The only way to assess muscle fibre numbers is by counting a cross-section of them under the microscope. The study carried out by Stickland, Widdowson and Goldspink in 1975 showed that genetic make up of an animal (in their case: the pig) is far more important in determining the number of muscle fibres than is the nutritional treatment. Once embryonic development is complete there is no further increase in the number of fibres in the muscle.

In contrast to the other tissues of the body, bone grows by juxtaposition (depositing layer on layer). If the bones increased in size in proportion to the body without changing shape, the strength of the bones (dependant on cross-sectional area) would increase as the square while the mass cubed, resulting in a skeleton too weak to support the animal.

It follows from this that the weight of the skeleton is greater in relation to the body weight in a large species than in a small one and limits the size to which a land mammal can grow (Tanner 1967).

Another part of the body that changes as a percentage of the body weight is adipose tissue.

As a general rule there is very little adipose tissue in mammals in the early parts of gestation. Some of the aninmals such as mouse, cat, dog and pig are born with a negligeable quantity of lipid (between 1 and 2% of body weight). These animals as soon as they start to feed and grow, store fat. Their rate of deposition is very rapid for most of the time, i.e. in the rat the fat percentage increases from 1 to 16 in the first two weeks, while in the pig it increases for 1 to 10 in one week (Widdownson 1950). In contrast other

species (sheep and cattle) begin to accumulate lipid in adipocytes (fat cells) in small amount resulting in lipid contents of the body at birth between 2 and 4%.

At birth the body fat of many newborn animals consists of brown adipose tissue which is physiologically, metabolically and morphologically different from white adipose tissue (the major fat depot of adult animals). Leat and Cox in 1980 suggested that the major role of brown adipose tissue appears to be the maintenance of body temperature particularly during the critical period immediately after birth. Compared with white adipose tissue it has smaller cell size, is richly vascularised and metabolically very active. It responds rapidly to changes in ambient temperature, mobilisation of fatty acids is triggered by the release of noradrenaline from sympathetic nerve endings and the fatty acids are immediately oxidised producing large amount of heat (Nicholls 1977).

2.2.4 Growth From Birth To Maturity

This section will review postnatal growth of the lamb until maturity is reached, and the various factors that affect its growth and development.

After birth a lamb's growth rate is initially influenced by the energy intake which is proportional to live weight. Theoretically growth rate remains fairly constant from birth to half way to maturity; then it will gradually decline to zero at maturity. Environmental factors such as feed, temperature, parasites, also breed and sex effects can drastically modify growth rate and body tissue development. Growth during the suckling period is dependent on the quantity of milk provided by the mother and also by the litter size (single or twin lambing). Growth rate, in absolute terms, is usually much greater during the suckling phase than during gestation. On the other hand, post weaning rates of growth are higher than those during the suckling period, providing that nutrition is adequate (Black 1983).

2.2.4.1 Postnatal Growth of Organs and Tissues

Differences in the relative growth rate of organs and tissues continue throughout postnatal life. In general tissues classified as "early maturing" are tissues which are a greater proportion of their mature weight than is body weight, or which increase in weight at a slower relative rate than body weight over the postnatal period. Tissues with a greater growth rate are classified as late maturing (Lohse et al 1971).

Most internal organs in sheep are early maturing, with the exception of parts of the digestive tract and organs associated with sexual development. The general classification of maturation rate remains similar between breeds and sexes (Kirton et al 1972).

Of the major body components, the order of maturation is skeleton, muscle and fat - with fat being classified as late maturing. In 1970, Fourie, Kirton and Jury in their study about growth of sheep with breed and sex effects, concluded that in general terms as lambs grow and mature, they are laying down muscular tissue at 91 to 97% of the rate that the carcass as a whole grows; that fat is laid down at a very much faster rate; and that bone is laid down at between 63 and 77% the rate that carcass increases. Although all fat depots are classified as late maturing, they differ in their mode of development, maturing in the following order: intermuscular and udder or cod, channel fat, kidney fat, internal fat (mesenteric), subcutaneous fat and omental (intestinal) fat (Kirton et al 1972).

The allometric approach has established some breed differences in the growth rate of different organs and tissues relative to body growth. These differences appear between breeds which are compared at the same

weight in carcass composition and the relative distribution of muscles and bones, but when compared to the same percentage of mature weight, the observed differences become insignificant or disappear (Taylor et al 1980).

Differences occur between genotypes in the pattern of development of major body components. Males have a greater postnatal development of the bones and muscles of the head and neck region than do females (Kirton et al 1972).

2.2.4.2 Factors Affecting Chemical Composition of the Whole Body

Growth may be considered from at least two aspects. Firstly, an increase in body mass (body weight) with time and, secondly, the changes in form or composition resulting from growth rates of the different body components.

Thus the growth pattern of the whole body is a composite of the growth curves of all its components.

2.2.4.2.1 Body Components and Their Evaluation Means (Techniques)

Measurement of changes in body compounds is much more complex than assessments of body weight itself. There are two approaches, the first involving slaughter of animals and the second dealing with measurements taken from live animals.

2.2.4.2.1.1 Slaughter Technique

Animals are slaughtered at the beginning and end of an experiment or at various weights and/or ages during a treatment period. This technique consists of the killing of the animal, an exsanguination is performed, the animal blood is collected and weighed, the animal is then dressed by the routine abattoir procedure, the contents of the gastro-intestinal tract are discarded, (sometimes weighed), the gastro-intestinal tract is weighed and packaged in sealed plastic. Similarly the carcass is weighed and broken down into portions of various sizes, placed in sealed plastic bags, and the plastic bags containing the different body components are frozen at -20oC. On removal from cold storage the frozen blocks are weighed to determine loss during storage. The different body parts are ground, sampled and analysed chemically (Lipid, nitrogen, water and ash) (Morris et al 1964).

ash) (Morris et al 1964).

Procedure for dissection and definition of tissue components fluctuated from worker to worker (Armsby and Moulton 1925, Walker 1961 and Butterfield 1962). Complete separation of tissues is never achieved in practice. For instance fat surrounding muscle can be separated but the intramuscular fat is impossible to isolate.

The slaughter technique has the serious limitation of permitting only one measurement to be made per animal. Also it is a costly operation because of the labour involved and the number of animals required.

2.2.4.2.1.2 Body Composition in Vivo Technique

So that a bettter understanding of growth might be achieved sequential measurements have been made on live animals throughout their lives. Measurement of body water is now a technique in common use in experiments in body composition (Till et al 1961). This technique achieves two things, it permits the determination of the water pool itself as well as

allows the calculation of the other major components, fat, protein and minerals. Body water can be determined by dilution of a tracer and the calaculation of chemical compostiion of the body is possible because of the close relationship between chemical fat and empty body weight (Robelin 1975). This esitimation method can be described by four steps:

(a) measurement of tracer dilution space;

(b) relationship between this space and total body water;

(c) relationship between fat and body water (at a given body weight);

(d) estimation of body fat, lean body mass, protein, energy and mineral from body weight and tracer dilution space.

Numerous compounds have been used: urea, suffanilanud, antipyrine, N-aminoacetylantipyrine, deuterum, tritium (tritiated water). The most widely used compund is water itself labelled with either deuterium (D_2O) or tritium (TOH). In 1961, Paneretto and Till preferred

the use of tritiated water (TOH), because TOH space yielded an unbiased estimate of the total body water (in contrast to the antipyrine (AP) space) of 11 mature goats, whose body fat varied from 0.5 to 22.8% live weight. Also the use of TOH or D_2O spaces presented the advantage of not being significantly metabolised during determination, thus eliminating serial sampling which was necessary when antipyrine was used (Till et al 1961).

The prediction "In Vivo" of body composition from tritiated water space is a simple procedure with minimal interference with the animal and its management (Searle 1970).

Tritiated water technique (as in any dilution technique) relies on a constant relationship between the fat free component and water. This theory is tangible for other animals but great caution must be taken when using young animals such as lambs. For instance: the basal metabolic rate of growing lambs is higher than that of mature sheep, and this affects the labelled hydrogen with the tissues and therefore the estimation of body water and fat from TOH space (Graham 1967).

The comparison of tritiated water space with data from slaughtered animals, enabled the establishment of prediction equations which, under adequate conditions can be used with confidence (Searle 1970).

2.2.4.2.2 Age and Body Weight

Growth curves reflect the lifetime interrelationships between an animal's inherent impulse to grow and mature in all body parts and the environmental effects which influence the manner in which these impulses are expressed. Generally growth is expressed in terms of size/age, weight/age. However, to presume that there is an effective relationship between age and body weight (or body composition), is unfounded. Age *per se* does not induce growth, but cumulative feed (nutrient) consumption triggers the growth mechanism, instead of cumulative time (age). Since records of lifetime feed intake are rarely taken, age is generally the best available "independent" variable (Fitzhugh 1976).

However there is a causal relationship between body weight and body composition. The weight of the chemical components of the body of the growing animal increases as the body weight increases, and the

proportions of the body components one to another change. In other words, each increment of body weight increases, and the proportions of the body components one to another change. In other words, each increment of bodyweight contains a different proportion of fat, muscle and bone (Fig. 1). Huxley (1932) demonstrated experimentally the fixed nature of the relationships betwen body components during growth. He established the fact that within a species or genotype the weight of a particular tissue or organ was related to bodyweight by the following allometric equation:

$$C = a\ W^b$$

Where C = weight of a component of the body

W = body weight

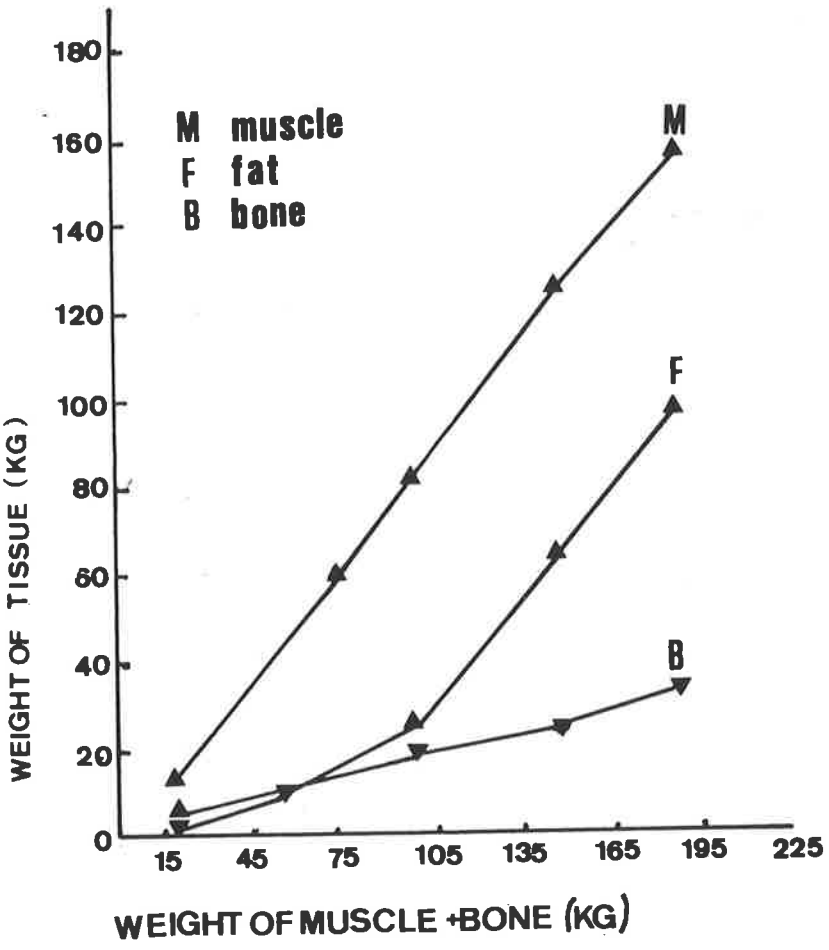
a,b = are constants

The logarithmic transformation of this equation gives a straight line for each body component plotted against body weight. This allometric equation has been used widely and is most useful for describing differential growth (Fowler 1968). This equation implies that growth is a continuous multiplication process, which is not always the case. The pattern of growth at the cellular level can be divided to three phases:

FIGURE 1

TISSUE GROWTH PATTERNS IN STEERS

(Adapted from Berg and Butterfield 1968)


M muscle
F fat
B bone
M
F
B
180
160
140
120
100
80
60
40
20
0
15
45
75
105
135
165
195
225
WEIGHT OF TISSUE (KG)
WEIGHT OF MUSCLE +BONE (KG)

(a) Phase 1 - Hyperplasia, multiplication of the cell numbers.

(b) Phase 2 - Transitional phase.

(c) Phase 3 - Hypertrophy, enlargement of the existing cells.

Greenwood and Hirsch (1974) in their study of adipose tissue growth in the rat concluded:

(a) An early period of cell proliferation until weaning (Hyperplasia).

(b) From weaning to puberty, cell proliferation continues but at a very decreased rate, while adipose cells continuously increase in size (transitional phase).

(c) After puberty, tissue growth results from cellular enlargement alone (hypertrophy).

In 1956 Joubert reached the following conclusion: muscle cells in sheep increase only in diameter after birth, cell number remaining constant. However, there does seem to adipocyte proliferation in some animals in the first year (Hood 1982).

Thus on biological ground, the application of the allometric equation to body composition is questionable. Therefore a mathematical model, based on recognisable biological concepts was developed by Searle and Colleagues (1972). It comprised four biologically discernable phases:

1. milk feeding (birth to three weeks of age);
2. rumen development (3-9 weeks of age);
3. prefattening ruminant (9 weeks of age to a body weight of 25-35kg);
4. fattening ruminant (above 25-35kg of body weight).

The first phase of growth of lambs represents the period where milk being the only component of the diet, is channeled by the oesophageal groove (bypassing the developing rumen) to the omasum and abomasum. The growth of milk fed lambs follows the monogastric pattern. Lambs and piglets which were milk fed gained an average of 0.19kg fat and 0.155kg of protein per kg of gain respectively (Searle 1970).

Phase 1 resumes in sheep with the introduction of dry feed in the diet which stimulates reticulo-rumen development. By the eighth week of age, the

concentration of volatile fatty acids reaches adult levels (Wardrop et al 1961).

The "rumen development" phase or phase 2 (3-9 weeks) is a transional phase and the body composition studies show that the total water content is higher than in Phase 1, the protein content similar and fat content less.

In Phase 3 (prefattening phase) and Phase 4 (fattening phase) the relationship between fat and body weight is linear and parallel in the higher weight range and between animals of all breeds (Searle et al 1976).

The rate of fat deposition increases markedly at an empty body weight (which is body weight less gut content) between 10 and 35kg. In the prefattening phase, the average composition of one kg live weight gain is as follows: 35% fat, 12% crude protein and 48% total water. While in the fattening phase every kg of live weight gain is composed of 66% fat, 9% crude protein and 24% total water. However many workers (Watson et al 1956 and Cannon et al 1969) suggested that the start of the fattening phase coincides with physiological changes such as puberty. This may have been purely a coincidence however as often these occurrences take place at about the same age.

Further studies have shown that milk fed lambs started to fatten below 20kg body weight well before gonadol development or the onset of puberty (Searle 1976). Hodge (1974) stated that milkfed lambs showed a more efficient use of metabolisable energy for maintenance than milk fed piglets. On the other hand it has been demonstrated that energy losses associated with ruminal fermentation of a high-quality diet are 20% greater than those recorded for enzymatic digestion in the lower tract. The energy available to a milk fed lamb is approximately 39-45% higher for maintenance and 22-61% higher for production than energy allocated to a ruminant lamb. (Fowler 1968). Subsequently the amount of protein absorbed and destined for tissue synthesis by ruminant lamb is 46% lower than that utilised by milk fed lamb (McDonald 1968). There is an interaction between protein and energy intake and their effect on fat content. The differences in fat deposition resulting from alterations in protein content of diets (milk fed lambs vs ruminant lambs) are much greater and theoretically can exceed 50% of body weight (Black 1974).

Most variation in body composition in sheep is closely related to the amount of fat. The amount of protein, water, and ash are linearly related to the weight of fat-free body for animals of different genotypes

subjected to various nutritional treatments. The body composition of sheep is subjet of the physiological state and/or the nutritional history (Black 1983). Searle and Griffiths (1976) stated that at body weight above 40kg, the influence of previous nutrition on the degree of fatness of sheep of the same breed and sex is less pronounced.

2.2.4.2.3 Sex, Breed and Maturity

The most important economic components of body composition, in regard to carcass value, are percentage lean and percentage subcutaneous fat. Since the latter, its subjective assessment by stock agents is used to indicate the yield of saleable lean. Intrinsic factors that influence body composition can be breed, sex and maturity (Wood et al 1980).

Difference in body composition due to sex become apparent at the beginning of the fattening phase of growth. Females enter the fattening phase at lower body weights than males. Thus in sheep females are fatter than males at all body weights above 15kg, but have less protein only at the higher body weights (Searle et al 1976).

However, when compared at the same carcass weight, wether carcasses have less fat and more protein content than the ewes, but the differences are smaller than between entire males and females (Kirton et al 1982).

Genetic differences influence the patterns of growth and body composition. For instance, when compared at the same weight, breeds (genotypes) which are heavier at maturity generally grow faster, contain less fat and more protein and bone than do animals of smaller mature size. Conversely, the less the mature size, the earlier a fixed body fat content is observed (Therriez et al 1981).

The breed differences in growth rate and body composition are mainly due to differences in mature body size. The larger breed is born heavier, grows faster at any age and starts to fatten at a relatively higher body weight. Its calorific values of weight gain are below over a greater body weight range than that in breeds of small mature size (Reid et al 1968).

The live weight at which occurred the transition between the prefattening and fattening ruminant phases varies and is characteristic of the breed. Searle and

Griffiths (1976) reported that Camden Park Merino, Medium Pepin Merino strains and fixed half-bred (Border Leicester x Merino) wethers entered the ruminant fattening phase at 22, 26 and 32kg fleece free fasted live weight. While Therriez, Tissier and Robelin stated that their Charmois, Limousin breeds and cross bred lambs (progeny of Berichon Rams mated to F1 (Romanov x Limousin) ewes) entered the fattening phase at 204, 281 and 306 days of age respectively for Charmois, Limousin and cross bred lambs.

However breed differences are not always clearly established. McClelland, Bonaiti and Taylor (1976) observed in their Breed Difference Study that the Finnish Landrace sheep were twice as heavy at maturity as the Soay sheep but was nearly equally maturing. Also they reported that the Southdown breed (small mature size) was as slow to mature as the larger Oxford down breed.

In general, breed comparisons are structured on the basis of slaughter at a constant weight, or the market weight. In such comparisons the results obtained can be misleading, and are confounded by mature body weight and degree of maturity (McClelland et al 1976).

An animal is mature when all its tissues are mature, and an early maturing tissue is defined as a tissue that reaches maturity earlier than the other tissues of the body. Also an early maturing tissue is viewed as a tissue that completes a certain proportion of its maturing process earlier than the body as a whole completes that same proportion of its maturing process. Conversely a late maturing structure is one which has achieved a smaller proportion of its mature weight than has the whole body of its mature weight (Butterfield et al 1983).

Degree of maturity is closely associated with some criteria used by producers when deciding when sheep or cattle attain slaughter criteria.

The stages of maturity are defined as the time when an animal reached a body weight that is close to being a percentage (i.e. 40, 60, 70%) of its estimated mature body weight. McClelland, Bonaiti and Taylor (1976) estimated the mature weight (M) of female lambs from the following equation:

$$M = 0.35D + 0.65D$$

Where D is the mature weight of the dam

D is the least squares mean weight of mature ewes.

And for male lambs, the estimates of M were increased by a factor 1.30 which is the ratio of mean mature weight of males to that of females (i.e. 30% greater).

Comparison of genotypes at equal weight and at equal proportion of maturity will give little difference in body composition. The differences due to sex and most of those due to breed are removed when body composition analyses of breeds from vastly different mature sizes, are based on the same percentage of mature weight (McClelland et al 1976). Thus most of the differences in body composition observed between breeds compared at the same weight reflect differences in relative maturity of these genotypes.

However Thompson, Butterfield and Perry (1985) found that their mature Merino rams had 30% total body fat - a value 8% lower than of mature Merino rams from a previous experiment (Butterfield et al 1983). This

difference between studies could be due to a combination of genetic and environmental factors. It has been pointed out that mature weight and maturity may be altered by environmental factors such as temperature, nutrition (Park 1982).

In order to use the maturity concept, it is necessary to estimate both the weight and composition at maturity from animals raised in the same environmental conditions.

2.2.4.2.4 Nutrition

This section will be brief as the following chapter is to be completely dedicated to animal nutrition and feed intake.

Both the plane of nutirition and feed chemical composition play a major role in animal growth and body composition. The effect of nutrition on body composition is on body fat - the fat-free tissues retaining an almost constant ratio one to another (Black et al 1976).

However there are contradictory reports on the influence of nutrition on body fat, although these had been reconciled by Black (1974), through an understanding of the partition of metabolizable energy between maintenance requirements, protein synthesis lipogenesis and heat loss due to nutrient utilisation. Black's simple and elegant model predicts that increases in the plane of nutrition will increase the animal's total body fat when given a high protein intake. Animals with high intake of a diet of sufficient protein will grow faster and be fatter at any body weight than animals fed similar diet with a lower intake. In contrast to animals fed adequate protein, a severe protein deficiency will result in a decline in the ratio of fat to protein in the gain as feed intake increases. And at some intermediate protein intake, there will be no effect of feeding level on body composition.

CONCLUSION

Foetal growth is determined initially by the rate of nutrient exchange between the foetus and the mother. Other factors influence its growth such as the sex and genotype of the foetus, litter size, body weight and condition of the ewe. Maternal nutrition plays a

major role in the growth and survival of the unborn lamb. Finally the environmental factors such as temperature and disease influence foetal growth.

Both hyperplasia and hypertrophy contribute to growth in sheep. It is generally accepted that in growing animals, hyperplasia ceases soon after puberty for most organs. Variations in organ weight within an adult animal appear to be almost due to change in cell size, whereas differences between breeds result mainly from variations in cell number.

During the postnatal phase, growth rate and body composition of an animal are influenced by sex, genotype and stage of maturity as well as by nutrient intake and composition of the diet and environmental conditions. There is no simple relationship between growth rate and body composition of sheep. However from a careful understanding of the partition of absorbed nutrients between various body functions it might be possible to understand (to translate) the associations between these characteristics in specific conditions.

2.3 FEED INTAKE IN GROWING ANIMALS/EFFICIENCY OF GROWTH

2.3.1 Introduction

Ruminants are characterised by a multicompartmented stomach having four parts: rumen reticulum, omasum and abomasum (the single stomach of monogastrics). The ruminant gut and its contents can account for 20% or more of body weight (Baile et al 1974).

Ruminants do not secrete cellulase, the enzyme responsible for breaking linkages of cellulose. However a symbiotic relationship existing between the animal and anaerobic bacteria in the rumenoreticulum which allows the utilisation of large amount of cellulose. Rumination which is a complex and distinctive regurgitation process increases cellulose fermentation. The ability to utilise cellulose is of great economic significance as it allows the utilisation of poor quality vegetation.

Although the voluntary intake of a feed is defined as the amount eaten when the intake is controlled by the animal rather than by the producer (farmer); while with housed animals, is identified as the amount eaten when an excess of some 15% is available (Heaney 1973).

The aim of this chapter is to review voluntary feed intake in ruminants, its mechanism control and factors which effect it.

2.3.2 Mechanisms of Intake Control

Regulation of feed intake and control of energy exchange seem to be triggered by common mechanisms. The numerous physiological functions concerned involve reflex responses, the central nervous system integrative function and chemosensitive areas (Conrad 1966). However a close relationship prevails between the amount of indigestible plant residues present in the gut and the quantity of feed consumed.

The fundamental concept of feed intake regulation stiputlates that feed intake should not be viewed as an independant variable but an integrated function to the other physiological functions such as growth, fat deposition and production (milk, wool, meat). It is evident that the functions are regulated individually as well as together (Brobeck 1960).

In 1947 Adolph came to the conclusion that food intake must be one of the best regulated of animal functions. Control of feed intake is multifactorial, also seen as a viatal component in the regulation of energy balance in the animal (Hervey 1971).

The terminal regulatory centres are located in the brain. In the eighteenth and nineteenth centuries it was believed that feed intake was initiated by the sensation of hunger originating from peripheral receptors situated in the alimentary tract. While another hypothesis made the assumption that food intake control was invested in the brain (Anan 1961).

Electrical stimulation of different sections of the brain have shown that regulation of feed intake is controlled by hypothalamic mechanism. It is believed that the lateral hypothalamic areas control the mode of eating behaviour by responding to sensory characteristics of the feed and by monitoring the onset and decay of satiety after eating. The activity of the lateral areas is controlled by feed-back from the ventro-medial hypothalamus. The function of the ventro medial area is thought to be the meter which indicates the level of nutrient stores in the body and regulates the satiety controls in the lateral area in

order to establish a set-point for nutrient energy stores (Panksepp 1974). However it is still believed that in some situations, intake control is extra hypothalamic and that feed intake control relies on control systems stretching from peripheral control in the gut to higher centres in the brain (Morrison 1977).

The mode of action of the signals to the control centres in animals is not fully understood. It is thought that the signals which indicate satiety levels for short-term control, include nervous impulses arising from:

(i) receptors in the gut lining;
(ii) body temperature changes;
(iii) hormones; and
(iv) changes in the plasma concentration of metabolites resulting from digestion process.

Concerning the long-term energy balance stability, which is observed in the mature animal, the assumption that the size of the fat reserves might be the best indicator of energy status, is regarded as the most plausible (Kennedy 1953). The pathway for transmitting the information of the energy status to

the hypothalamus, is still at the hypothetical stage. Bray (1986) detailed the autonomic hypothesis. (The autonomic nervous system consists of the nerves that control heart muscle, glands and smooth muscles, muscle found in walls of blood vessels and in the digestive, respiratory, and reproductive tracts). It is generally classified as an "involuntary" system, in contrast to the somatic system which controls skeletal muscles (Curtis 1979). The destruction of the ventromedial hypothalamus induces hyperphagia in mammals (Bray et al 1979). While destruction of the lateral hypothalamus causes a reduction of food intake and in extreme cases total aphagia (Yoshida et al 1984). The destruction or stimulation of either ventro medial hypothalamus or lateral hypothalamus is related to functional changes in the autonomic nervous system (see Fig. 2).

The autonomic hypothesis proposes that the ventromedial hypothalamus and lateral hypothalamus control metabolism through reciprocal modification of the two branches of the autonomic nervous system. Also Bray (1986) pointed out the importance of hormones in feed intake regulation. The levels of insulin, adrenal steroids, gonadal steroid and growth hormones influence energy balance.

The sympathetic nervous system is inversely associated with energy storage or put another way, high sympathetic activity is related to lower fat storage. However the expression of intake control is through feeding behaviour which eventuates during meals or grazing periods. The grazing patterns are affected by extrinsic factors such as environmental conditions but the quantity and frequency of the intake is dictated by intrinsic factors such as the animal's energy demands (Freer 1981).

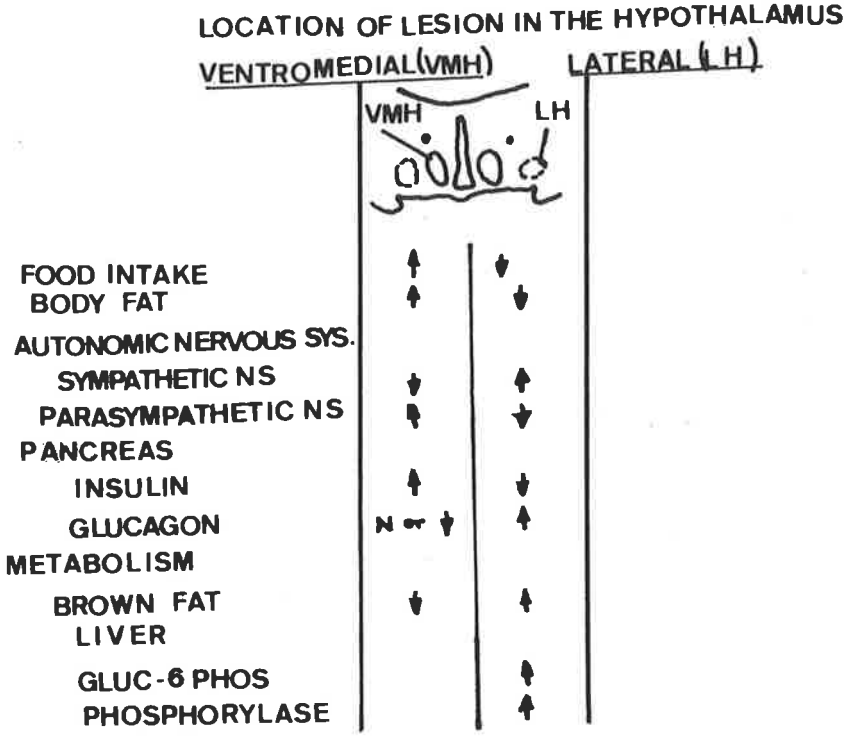
2.3.3 Effect of Diet on the Voluntary Feed Intake

The regulation of feed intake by animals is an important life-sustaining process, intimately connected to the overall energy metabolism of the organism. Ruminants, like other species, adjust their food intake to their nutritional requirements, or their potential energy demand (Dulphy et al 1979).

However the type of diet may influence the feeding behaviour of the animal. For instance, an animal that is unable to harvest enough nutrients to meet its energy requirements, will be faced with depressed growth and lactation and its nutrient stores will be depleted.

FIGURE 2

COMPARISON OF THE PHYSIOLOGICAL AND METABOLIC CHANGES THAT ACCOMPANY DESTRUCTIVE LESIONS OF THE VENTRO-MEDIAL HYPOTHALAMUS (V.M-H) AND LATERAL HYPOTHALAMUS (LH)


LOCATION OF LESION IN THE HYPOTHALAMUS
VENTROMEDIAL(VMH)
LATERAL (LH)
VMH
LH
FOOD INTAKE
BODY FAT
AUTONOMIC NERVOUS SYS.
SYMPATHETIC NS
PARASYMPATHETIC NS
PANCREAS
INSULIN
GLUCAGON
N or
METABOLISM
BROWN FAT
LIVER
GLUC-6 PHOS
PHOSPHORYLASE

Limitations to feed intake seem to be dictated by the functioning capacities of diverse physiological processes. The phyisiological processes responsible for feed intake limitations are:

(a) digestion of feed and the passage of residues through the digestive tract;

(b) allocation of absorbed molecules to appropriate sites for synthesis, oxydation and excretion;

(c) adaptation to environmental stresses.

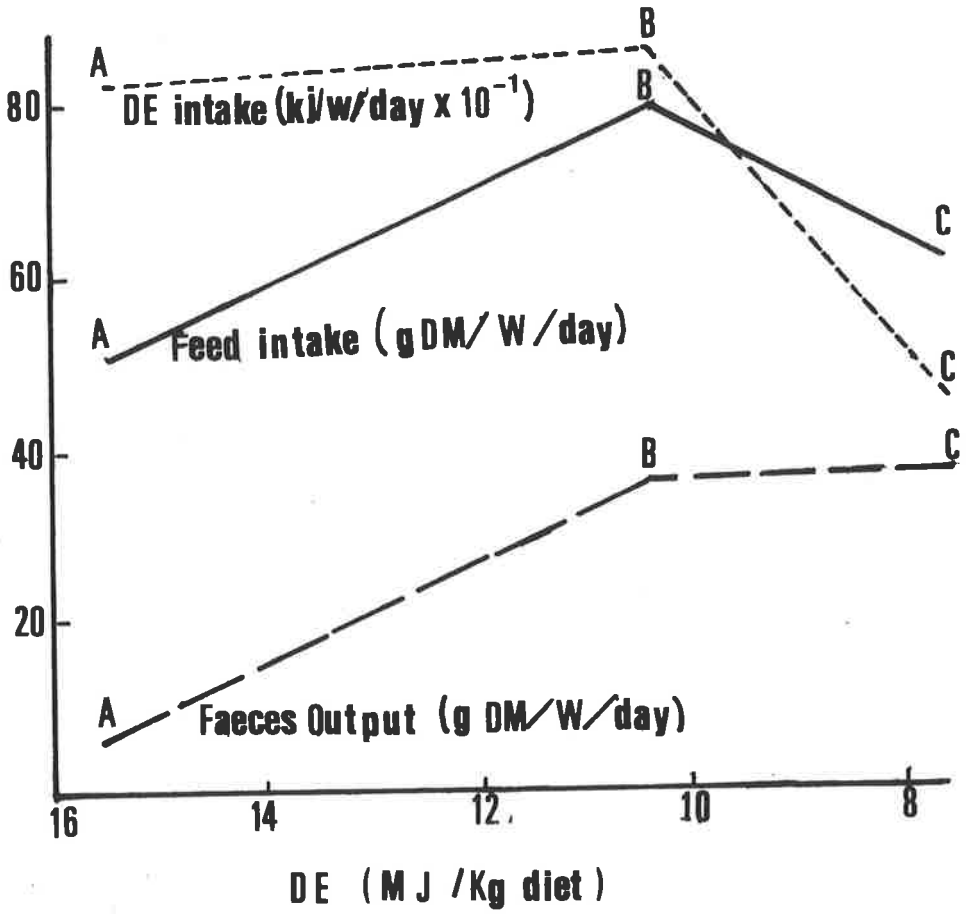
2.3.3.1 Gastrointestinal Tract Limitation to Feed Intake

Feed intake is limited by the propulsive capacity of the alimentary tract. Dilution of a diet with indigestible material initially results in an increase in intake to maintain the intake of metabolizable energy , but only up to a point which is associated with a critical distension of the alimentary tract during eating. A drastic decrease in digestibility will lead to a lower energy intake (see Fig. 3) (Weston 1979).

FIGURE 3

RELATIONSHIP BETWEEN THE DIGESTIBLE ENERGY (DE) CONTENT OF THE DIET AND DE INTAKE, FEED INTAKE AND FAECES OUTPUT FOR CONCENTRATE BASED DIETS

(Weston 1979)


A
B
B
C
C
DE intake (kJ/w/day x 10^{-1})
Feed intake (g DM/ W /day)
Faeces Output (g DM/W/day)
80
60
40
20
16
14
12
10
8
DE (MJ /Kg diet)

In practice grazing animals have access to diluted (non-concentrated) diets (pastures) and the signals for intake control are controlled by the effects of bulk in the alimentary tract. Thus the rate of removal of organic matter from the rumen can also be a factor controlling intake; due to the limited capacity of the rumen (Blaxter et al 1961).

On the other hand the food on offer may vary widely within and between plants and with time that affect diet selection. So intake may be limited by the time and energy required to harvest the pasture (Allden et al 1970). Voluntary intake appears to be related to the amount of digesta that can pass daily through the digestive tract, rather than to the potential energy requirements of the animal.

During the maturation process in herbage, the proportion of cell wall material steadily increases while potential digestibility and rate of digestion of the herbage decline (Wilkins 1969). As a result of these changes the time required for food particles to be reduced in size (by chewing and chemical digestion) before they can pass out of the rumen increases drastically and intake falls. Weston (1979) demonstrated (Table 1) the effects of plant maturation on digestibility, intake and chewing time.

Table 1 : Effect of Maturation on the Composition and on Voluntary Intake of Phalaris and Sub clover when Offered to Adult Merino Sheep

	PHALARIS			SUB CLOVER	
MATURITY	1	2	3	1	2
Cell wall constituents (CWC) as percentage of organic matter (OM)	44	63	75	39	57
Digestibility of CWC (%)	82	76	52	80	66
Voluntary intake of OM (g d-1)	1067	933	804	1226	827
Time spent chewing (min/kg)	530	840	1090	378	918

Laredo and Minson (1973) in their digestibility experiment found that the voluntary intake of the leaf fractions of different grass species was positively correlated with the dry matter digestibility but was always higher than that of stem of the same digestibility. Also the intake of legumes is greater than that of grasses when compared at the same level of digestibility (Ulyatt et al 1974). The dry matter digestibility coefficient is the quantitative reflection of the rate of disappearance of a roughage from the alimentary tract. It is an index that should be used with caution as it cannot be assumed to be adequate for comparing different plant varieties (Blaxter et al 1966). Differences in the organisation

of carbohydrates and lignin in the cell wall are important factors affecting the rate of digestion and the size of the digesta particles (Freer 1981). Thus in any study of voluntary intake of food, it is necessary to determine physical properties of the feed as well as its chemical composition.

2.3.3.2 Feed Intake Limitations due to Ruminant Metabolic Functions

Ingested susbstances are subjected to synthesis, oxidation and excretion, and these three metabolic pathways might indirectly limit the feed intake.

Firstly, the genetic make up of the animal might impose limits on the rate of nutrient use in production pathways, and secondly, nutrient deficiencies might impair metabolic pathways and consequently nutrient uptake or utilisation will be limited (Weston 1979).

It is a well established fact, that, under optimal dietary and environmental conditions, sheep consume feed in relation to their energy needs. When the energy concentration in the diet is altered, feed intake varies in order to supply a constant level of energy (Weston 1971).

The genetic capacity to convert the nutrients in productive processes not only dictates feed intake but also the level of energy storage. Metabolizable energy, which is that which is the surplus to other requirements, on good quality pastures, will accumulate as body fat until the capacity of storage is fulfilled. But no assumptions can be made about any "set point" or limit for body fat content or body weight, at which a sheep can maintain itself. Panaretto (1963) stated that sheep and cattle on a high energy diet, can reach advanced stages of obesity before weight stabilises. Freer (1981) made the assumption that the palatability of the diet offered, overpowered the regulatory system when sheep were fed on more fibrous feeds.

Selection, in the past, for high mature body weight and fat content, is responsible in the absence of a set point for body weight in the sheep. Wild species such as the deer show seasonal fluctuations in body fat content controlled by day length. These levels of fat exist even in the presence of dietary changes indicating seasonally variable set points (Ammann et al 1973, Pollock 1975).

Alternatively, it may be that sheep and cattle body weights stabilise when the accumulation of abdominal fat restricts the rumen capacity significantly to reduce the voluntary intake. Declines in intake during long-term "ad-libitum" feeding were reported by Graham (1969), and it has been established that a close inverse relationship exists between fatness and intake with stable intake at high levels of fatness (see Figs 4a, 4b) (Forbes 1977).

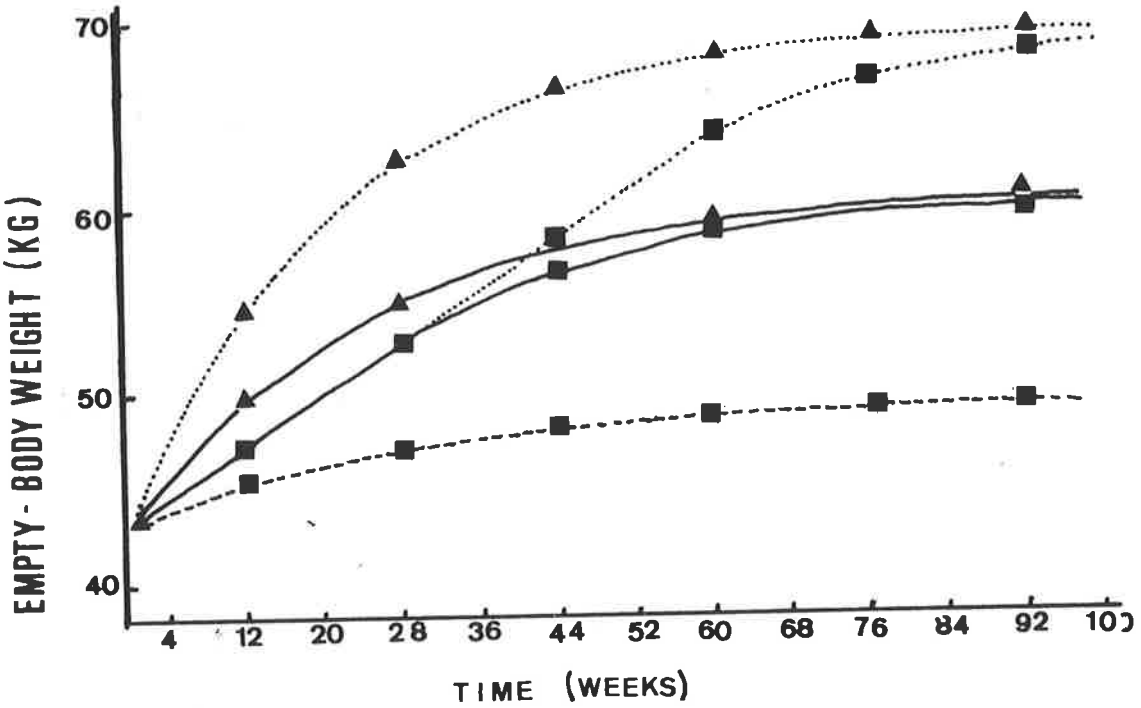
FIGURE 4

PREDICTED VOLUNTARY INTAKES OF THREE FEEDS BY FATTENING MATURE SHEEP, a) PREDICTED EMPTY BODY WEIGHTS (kg), AND b) FOOD INTAKE (g/DAY)

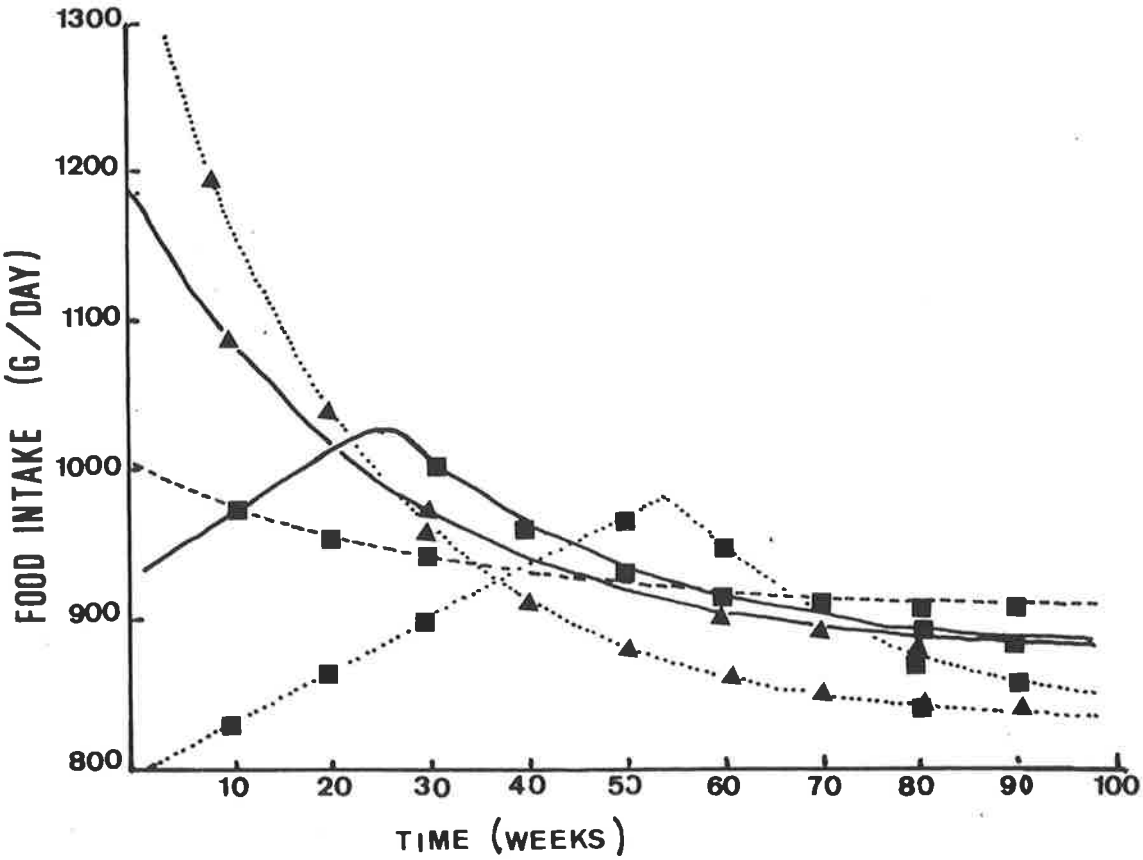
Where :

(.....) = 75 % D.M. Digestibility .
(_____) = 65 % D.M. Digestibility.
(------) = 55 % D.M. Digestibility.
(■) = 50 g / day , rate of fattening.
(▲) = 200 g / day, rate of fattening.

a)


EMPTY-BODY WEIGHT (KG)
70
60
50
40
4
12
20
28
36
44
52
60
68
76
84
92
100
TIME (WEEKS)

b)

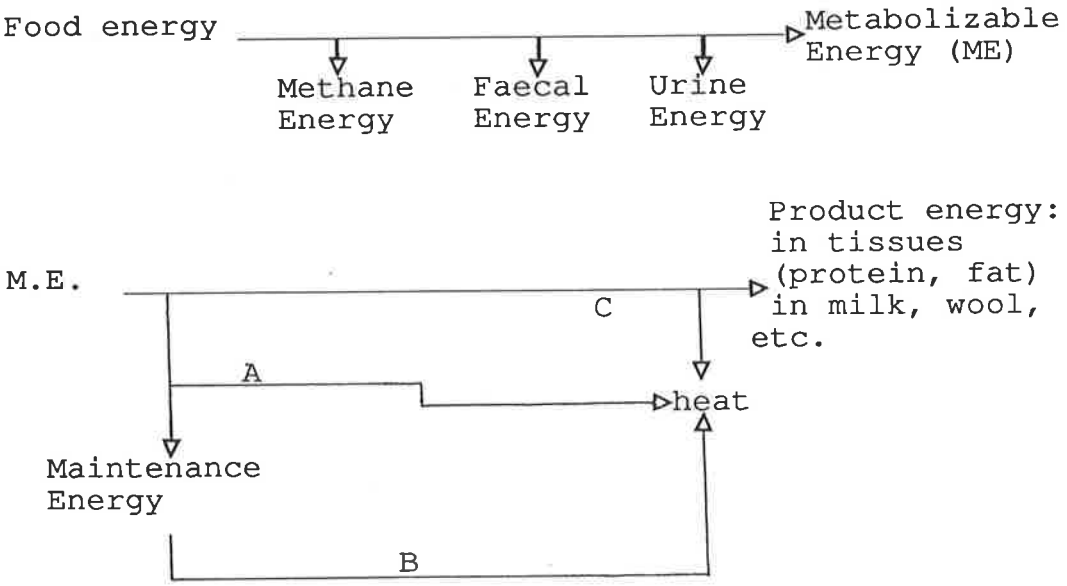

FOOD INTAKE (G/DAY)
1300
1200
1100
1000
900
800
10
20
30
40
50
60
70
80
90
100
TIME (WEEKS)

2.3.3.3 Feed Intake Limitations Associated with the Environment

Climatic extremes and restricted feed availabilities severely decrease feed intake, presumably related to limits being reached in processes concerned with hypo and hyperthermia, heat and water conservation and muscular activity.

2.3.3.4 Control of Feed Intake in the Regulation of Energy Balance

Control of feed intake can be viewed as a component of the homeostatic regulation of energy balance. Energy balance of an animal is determined by the difference between energy input (food) and energy output under the form of methane; faecal and urine energies, heat increment, plus the energy expended for maintenance, milk production, reproduction, wool production.



Metabolizable Energy (ME) is commonly used as the starting point of disucssions on energy utilisation, due to the fact that faecal losses vary from feed to feed and losses with urine and methane might decrease the energy value of the feed for the animal (Baumgardt 1970). ME is identified as the energy of the chemical compounds absorbed from the gastro-intestinal tract into the blood such as: fatty acids, amino acids, and monosaccharides.

In ruminants, carbohydrates are fermented in the reticulo-rumen, which is a process giving volatile fatty acids and methane as energy-containing compounds. The volatile fatty acids (VFA) are absorbed in the blood while the methane is lost by

eructation. Also the fermentation process does generate heat, but this heat is useful to the animal only at temperatures below 10°C, due to the fact that ruminants have a high heat production (Van Es 1980).

However the level of energy intake at which animals control feed intake varies with the physiological demand of a given animal at a given time. For instance lactating animals have a high energy demand while dry mature animals have a low energy demand. Fortunately, energy balance experiments with farm animals, have produced information on the amount of ME needed for each physiological state.

The volatile fatty acids (VFA) are an important energy source for ruminants and their concentration might be a factor controlling feeding due to the fact that they are produced in the forestomachs and nearly completely absorbed prior to passage to the abomassum. Also the rates of production and absorption are closely related to feeding patterns (Simkins et al 1965).

Feed intake decreases when volatile fatty acids are injected in the rumen, in sheep (Weston 1966) and also in cattle (Warner et al 1968).

Intraruminal injections of acetate, propionate or a mixture of both decrease feed intake, while butyrate is much less effective in depressing feed intake (Baile et al 1970). Feed intake is influenced by a concentration change in volatile fatty acids, acetate and propionate in the rumen which can affect receptors on the lumen side of the rumeno-reticulum and especially on the dorsal rumen.

However the ventro-medial hypothalamus might provide partially, a reference input which by its action on the lateral hypothalamus balances the energy of feed intake and body energy depletion (Baile et al 1974).

2.3.3.5 Fats in the Ruminant Diet

The term fat or lipid describes a wide variety of compounds that are water insoluble and dissolve in organic solvents (chloroform, diethylether). From a nutrition point of view the main lipids are triglycerides, phospholipids, sterols and fat soluble vitamins.

The lipid content of forage crops is low (5-10mg lipid per 100g dry plant tissue). The lipids of plants are usually concentrated in the leaf chloroplast which amounts 2-5g lipid per 100g dry matter, and consist

mainly of phospholipids and glycosyldiacylglycerols (Menke 1966). Linolenic acid, linoleic acid and oleic acid account for a high proportion of the total fatty acids, with respectively 53, 13 and 10% of the forage material (Garton 1960).

Fats and oils are constituents of both plants and animals, and are important sources of stored energy. Acetyl-ester bonds of dietary lipids are quickly hydrolysed in the rumen resulting in absorption of unesterified fatty acids on to particular matter (Harfoot et al 1973). Also since unsaturated fatty acids are rapidly hydrogenated in the rumen, then the lipid associated with food particles consist mainly of unesterified saturated fatty acids.

From a quantitative point of view, fat absorption in ruminants shows a high level of efficiency. Coefficients of digestion of 80 to 90% have been reported for a range of fats, oils and fatty acids by several authors (e.g. Heath et al 1969, Andrews et al 1970). Heath and Hill (1969) observed that 90% of the fatty acids entering the intestine would be absorbed, even when the dietary fatty acid intake was significantly increased.

In general, ruminants demonstrate a greater ability to absorb C-16 and C-18 fatty acids than monogastrics. The difference between the species might be due to the greater degree of dispersion of long chain fatty acids in intestinal content of ruminants, and the bile-salt/lysophosphatidylcholine micelles have a higher solubilisation rate of saturated fatty acids then bile-salt/2-monoacylglycerol micelles (Lough et al 1976).

However, when ruminants are fed with diets containing "protected" fats or oils, large amounts of triacylglycerols enter the duodenum. Under these conditions, the digestion mechanisms of the dietary triacylglycerols and liberated fatty acid solubilisation will be similar to those observed in the non-ruminant small intestine where the 2-monoacylglycerols play an important role in the micellar solubilisation of fatty acids (Thompson et al 1981).

2.3.3.6 Efficiency of Production

Blaxter (1968) defined biological efficiency as a measure of the ability of a species to survive, reproduce and maintain its numbers in a given environment or habitat. In general, biological

efficiency can relate to any measure of the efficiency with which biological process is carried out for a biological purpose. It can be simply defined as a ratio of units, functionally related, or a ratio of "output" per unit "input" (Spedding 1973).

Biological efficiency in animals is dependent on the relationships between input as feed initially, and the cost of maintenance plus the value of output. The terms of the relationship can be expressed in energy units or of any nutrient involved in animal metabolism.

The ratio output:input is referred to as efficiency, while the inverse input:output as utilisation or conversion (e.g. feed conversion ratio).

Holmes (1971) gave the generalised equation form to estimate the overall efficiency of an animal product thus:

$$E = \frac{\text{Product in Time t (Gain and/or milk, wool, eggs)}}{\text{Total maintenance} \quad \text{Total milk, eggs} \quad \text{Total gain}}$$

or

$$E = \frac{P}{\frac{M}{Km} + \frac{Milk}{Kl} + \frac{Eggs}{Ke} + \frac{Wool}{Kw} + \frac{Total\ gain}{Kf} - \frac{Total\ loss}{Km}}$$

Where P: is expressed as product or energy, Protein
E: is expressed as a decimal
Km: is expressed as a decimal and is the efficiency of use of the nutrient for maintenance
Kl: expressed as a decimal and is the efficiency of use of the nutrients for Lactation
Ke: efficiency of use of nutrients for egg
Kw: efficiency of use of nutrient for wool
Kf: efficiency of use of nutrient for fattening

If the equation is in energy units, then E is "gross efficiency" or the ratio net energy/gross energy. The efficiency takes its term from the denominator with the exceptions of those related to maintenance and total loss which are respectively referrred to "partial efficiency" and "net efficiency" (Brody 1945).

With respect to energy, (similar conclusions apply to other nutrients), the factors which can effect efficiency are (Blaxter 1965):

(a) Intake - Ratio $\frac{\text{Voluntary feed intake}}{\text{maintenance feed requirement}}$ = relative feed level R.F.L.

It has been established that efficiency is at its highest when relative feed level (R.F.L.) is very high.

(b) Nutritive value: the composition of feed intake will dictate the animal's use of nutrients and its level of efficiency.

(c) Maintenance requirement relative to production requirements: environmental conditions will determine maintenance requirements, extreme environmental temperatures and forage scarcity will affect the animal nutrient requirement and utilisation.

(d) The composition of weight gain and other output: some modification of qualitive output might take place without change of quantitative output.

(e) Age and the age at which an animal reaches maturity: the relationship between age and efficiency depends on the period of time involved. Efficiency of growth declines with age.

(f) Efficiency of the complex biochemical processes to convert absorbed nutrients into lipid, and protein within the body.

Genetic variation in efficiency depends on variation of feed intake, variation in the metabolic product partition between maintenance, growth and production and the variation in the relationship between efficiency of body metabolism and age. These variations are difficult technically to investigate with precision. For instance feed intake of grazing animals can be estimated by indirect means such as the use of a slow release chomic oxide device, where there is room for error. On the other hand, pen fed animals are given controlled quantities of conserved forage which in themselves can influence the examination of variation of voluntary feed intake (Bowman 1973).

Sheep production efficiency is dominated by maturity. When animals are judged on a fixed body weight for traits such as growth rate, leanness and feed conversion efficiency this will undoubtedly favour the less mature animal and thus select for an increase in mature body size. Another alternative will be to select for growth rate or feed conversion efficiency to a given degree of fatness, knowing that fatness is closely connected to stage of maturity (Webster 1980).

Graham (1968) concluded from his experiment, that the relation between energy storage (fat) and food intake is virtually the same for fat or thin sheep. His thin and fat sheep showed the same "net efficiency" (utilisation of an increment of M.E.) at any level of energy storage relative to maintenance.

Since fat contains eight times more energy than protein and adipose tissue contains less water than muscle; it is assumed on a weight basis that leaner animals are surely the more efficient converters of feed (Pym and Solvyns 1979). Webster (1980) argued that if an animal is leaner because it is less mature than the assumption of being a better feed converter is valid. There is no close relationship between leanness and efficiency of growth when comparisons are based on similar degree of maturity. Under intensive conditions, a fast growing animal might retain no more than 30% of the consumed metabolizable energy (ME), in the form of body tissue, the difference is dissipated as heat. The proportion of ME destined to protein synthesis is around 8%. Under semi intensive conditions the proportion of ME deposited as protein in meat is less than 3% in beef cattle. While the proportion of ME assigned for fat deposition is influenced by genetics and nutrition, it only amounts to between 5 and 20% of ME consumed (Webster 1980).

In 1981 Webster reported that lean sheep had greater heat production than fat sheep when adjusted to body weight (0.75).

In summary, the efficiency of utilisation of ME by an animal is as follows: While an animal is growing, ME exceeds heat production (H), but as the animal reaches maturity the two variables converge. Efficiency of energy retention (RE) attains its maximum at about 25% of mature body weight and declines thereafter. The ratio of fat to protein in the body gains increases as an animal matures and the feed conversion efficiency is virutally constant during the first third of the growth and declines at about 30% of mature size (Thompson et al 1985a).

In conclusion there is often little difference in efficiency or rate of growth when comparisons are made at the same stages of maturity (McClelland et al 1973; Thompson et al 1983).

2.4 ANABOLIC AGENTS

2.4.1 Introduction

The future of livestock industry lies in the efficient production of palatable and nutritious meat products with the specification of being free of excess fat. This means that the animal industries must increase daily live weight gain and achieve a higher (better) feed conversion efficiency while at the same time improving carcass traits such as the "lean:fat" ratio.

Growth promotants have been used to improve the production and growth meat-animals by increasing the efficiency of feed conversion and also lessening fat in the carcass. They cover a wide range of substances with distinctive modes of action. This section will be dedicated to anabolic agents, their mode of action and their contribution to the production of a leaner animal.

2.4.2 Endogenous Hormones

2.4.2.1 Pituitary Hormones

The anterior-pituitary secretes three hormones that influence growth and body composition. Growth

hormone, which is a polypeptide is regarded as the principle hormone that influences postnatal growth. It has been established that growth hormone (GH) when administered increases nitrogen retention in sheep (Wynn et al 1979) and in steers (Mosley et al 1982). Sandles and Peel (1987) in their experiment with exogenous GH administered to youg pasture-fed dairy heifers, reported a significant increase in body weight gain and a small reduction in carcass fat. When bovine GH (bGH) was administered to young growing lambs, carcass composition and quality were improved (Buttler-Hogg 1987).

Two additional hormones secreted by the anterior - pituitary, prolactin and thyroid stimulating hormones (TSH), have been reported to possess anabolic activities, but their growth-promoting qualities are not well established (Schanbacher et al 1980; Muir et al 1983). Although these hormones might not have an intrinsic anabolic function, when combined it has been reported that they have an anabolic activity on growth. For example, the administration of exogenous GH and thyroprotein together increased the rate of net protein accretion compared with that measured when GH was administrated alone (Wagner et al 1978).

2.4.2.2 Insulin

The secretion site of insulin is in the pancreas by the β. cells of islets of Langherhans. Insulin is at the center of metabolic regulation. It plays a role in the regulation of glucose by inhibiting gluconeogenesis and glucose release from the liver, and also by stimulating the uptake and utilisation of glucose by peripheral tissues. Stimulation of lipogenesis and inhibition lipolysis are under control of insulin, as is amino acids and protein metabolism (Prior et al 1982).

2.4.2.3 Gonadal Steroids

Sexually intact animals produce gonadal steroids that effect growth and production performance.

Testosterone is associated with a positive nitrogen balance, accelerates linear growth and weight gain and increases carcass protein while carcass fat is decreased (Schanbacher et al 1980). Castration, the most common endocrine modification, by removal of the testes, will reduce the production of the male's endogenous anabolic steroids: testosterone and oestrogen. Castration has been traditionally practiced in order to produce a more attractive carcass for the

market place and to minimise flock management problems: castrated animals are often docile and rarely aggressive. Most of the intact male growth characteristics can be restored to castrated animals by the administration of exogenous androgens.

On the other hand it has been reported that oestrogens have an inhibitory effect on total body growth (Bernsten 1968). But there is an acceleration of growth in younger animals exposed to oestrogens. Preston (1975) suggested that oestrogens may act indirectly on growth through regulation of plasma growth hormone (GH), insulin and thyroid hormone.

2.4.3 Exogenous Hormones, Steroid Implants

It is possible to manipulate growth in farm animals by the administration of steroid implants.

Androgens increase growth rate by exerting their influence on muscle metabolism through their binding action on to specific muscle receptors (Spencer 1985).

The major androgens are:

2.4.3.1 Testosterone

Testosterone, secreted by the testis, improves growth rate and also induces secondary sexual characteristics. When injected it decreases carcass and kidney fat of castrated male lambs (Jacob et al 1972).

However, testosterone is not the only testicular hormone that improves performance of the growing animal. In the ruminants, anabolic effects are derived from both androgens and oestrogens. For instance the combined treatment of methyltestosterone and diethylstilboetrol (10:1 w/w) improved live weight gain and resulted in a significant increase in protein content of the 12th rib joint (Beeson et al 1956). When testosterone was implanted in combination with oestradiol - 17 B growth and nitrogen retention are improved in bull calves more efficiently than oestradiol treatment alone (Van der Wal 1976).

2.4.3.2 Trenbolone Acetate (TBA)

Trenbolone acetate is a synthetic androgen with a structure similar to testosterone. TBA has the anabolic qualities without affecting the secondary

sexual characteristics of testosterone. Administration of the anabolic agent, TBA, to cows, has stimulated growth and, by reducing fat deposition, improved carcass conformation (Galbraith 1980a).

Implantation of 300mg TBA (Finaplix 300), significantly improved body weight gain of heifers and shortened the time taken to reach slaughter weight (Best 1972). Sulieman, Galbraith and Topps (1981) in their study of the response of mature female sheep to TBA found that TBA increased the deposition of carcass lean tissue and internal depot fat.

The stimulation of growth rate by TBA might be due to changes (modifications) in nitrogen metabolism which cause an increased nitrogen retention and increment of protein in the carcass (Galbraith 1980b).

2.4.3.3 Trenbolone Acetate and Oestradiol

Trenbolone acetate in combination with oestradiol has been reported to increase growth rate and carcass traits in a more eficient manner than trenbolone alone (Van der Wal 1976).

In 1975, Grandadam and colleagues reported improvement in carcass weight of veal calves by 8.5%, feed lot bulls by 6.3% and castrated male lambs by 5.8% following the implantation of 20mg oestradiol - 17B plus 140mg trenbolone acetate.

2.4.4 Anabolic Agents and Their Use in Sheep

The studies of ovine responses to sex steroids are not as extensively documented as those in cattle. The short duration of the fattening (finishing) period has been a limiting factor in the use of anabolic compounds in sheep. Nevertheless it has been suggested that the responses of sheep to the use of sex steroids are similar to those obtained with beef cattle with the exception to sex differences which are not as pronounced (Roche et al 1986).

However, there is a great variation in the responses obtained. This might be explained by the use of a wide range of genetic material as well as the variety in the feeding conditions and management in practice in the trials.

Anabolic steroids are contraindicated in animals retained for breeding purposes. Estrodiol implants adversely affect testicular development in ram lambs (Riesen et al 1977). They may also delay the onset of puberty and reduce ovulation rate in female sheep (Roche et al 1986).

In conclusion, when anabolic agents are administered as implants, (fitted in the back of the ear) they increase feed intake, feed conversion and growth rate. They appear to increase the growth potential of an animal over-riding the genetic set points. The effectiveness of each compound depends very much on the sexual status of the animal, the animal type, age and diet. Finally the safety of the anabolic agents in human health terms must be considered, although the concentration of the natural hormones at least is less than in breeding males and females.

2.5 FAT TYPE

2.5.1 Introduction

The word "lipid" describes a chemically heterogeneous group of substances that have the property of water insolubility but solubility in non-polar solvents such as chloroform and alcohols. To have nutritive value, fats must be digested and absorbed from the gastro intestinal tract. From a physiological viewpoint, adipose tissues are regarded as energy stores which can be utilised by mammals during periods of negative energy balance. Also the rate of lipid deposition dictates the energy needs of animals; specifically their efficiency to transform feed to meat. The fatness at slaughter (total amount of fat) is the main determinant of the carcass quality.

In the ruminant lipid metabolism is strongly influenced by the events that occur in the rumen and which subsequently effect the chemical and physical nature of the lipids presented to the small intestine for digestion and absorption.

2.5.2 Fatty Acids

Fatty acids are the major ingredients of most complex lipids. The most common in animal tissues contain 12-24 carbon atoms. The main fatty acids can be classified as saturated straight or branched-chain fatty acids with an odd or even carbon atom number, and unsaturated fatty acids. The unsaturated fatty acids may contain between one to six double bonds, usually cis (where the hydrogen atoms lie on the same side of the double bond) with methylene group between neighbouring double bonds. While trans-unsaturated fatty acids (hydrogen atoms and double bond lie on opposite sides), are found in ruminants, due to fatty acid modification in the rumen (Enser 1984).

The degree of fluidity of lipids is of prime importance in lipid-containing structures and it is mainly determined by the fatty acids they contain. The melting point of the fatty acids increases with increasing molecular weight and those with 12 or more carbon atoms are solid at body temperature and their presence hardens fat (Gurr and James 1980).

Unsaturated acids have lower melting points than their saturated analogues, the presence of each additional double bond decreasing the melting point. Measurement

of the melting point thus provides an indirect measure of the fatty acid composition of a fat. Also the melting point depends upon the geometry of the double bond: trans fatty acids have higher melting point than their cis isomers, and on the position of the double bond within the chain: C18:1(W-9) (W refers to the position of the double bond in the chain), oleic acid (cis double bond) melts at 13.4°C, elaidic acid (trans isomer) melts at 43.7°C, while C18:1(W-11) (trans), vaccemic acid melts at 39.0°C (Enser 1984).

2.5.3 Biosynthesis of Fatty Acids

Adipose tissue and lactating mammary tissues are the major sites of fatty acid synthesis, in sheep, cattle and pigs in contrast to hepatic synthesis of fatty acids in man, the mouse and rat (Bauman 1976). In most tissues synthesis occurs in the soluble cytoplasm, or cytosol while the oxidation of fatty acids occurs exclusively in the mitochondria. The enzymes involved in fatty acid synthesis are bound together in a complex which acts as a single particulate component: fatty acid synthetase. The principal product of fatty acid synthesis is palmitic acid although saturated fatty acids with 10, 12, or 14

carbon atoms may also be formed. Since propionyl - CoA can replace Acetyl - CoA as an initiator of fatty-acid synthesis, odd-numbered fatty acids can be produced by the same enzyme complex.

The double bond formation of fatty acids is triggered by an enzyme system that is contained in the endoplasmic reticulum of mammalian cells in the liver and adipose tissues (Van Goilde and Van Den Bergh 1977). This enzyme system can form a double bond between carbon atoms 9 and 10 of palmitic and stearic acids, forming the two most common monounsaturated fatty acids: palmitoleic C 16:1 (W9) and oleic C 18:1 (W9) acids respectively.

Similar enzyme systems can introduce further double-bonds at three carbon intervals towards the carboxyl end of the chain. Unsaturated fatty acids formed by desaturation and chain elongation from palmitic and stearic acids, have the first double bond at carbon atoms 7 and 9 (counting from the methyl end of the chain) respectively. They form the two families of unsaturated fatty acids: the W7 and the W9 families. Another two families of polyunsaturated fatty acids need to be mentioned, the W:3 and W:6 families (Gunstone 1975).

However animals do not have enzymes capable of inserting double bonds beyond the ninth carbon atom of a fatty acid chain, then the precursors of these families, linolenic acid (C 18:3 cis 9, 12, 15) and linoleic acid (C 18:2 cis 9,12) have to be supplied in the diet and are termed essential fatty acids. These two essential fatty acids, linoleic and linolenic acids, and oleic acid give rise to groups of polyunsaturated fatty acids nominated W-9, W-6 and W-3:

(1) $CH_3 - CH_2 - CH_2 - CH_2 - CH_2 - CH_2 - CH_2 - CH_2 - CH = CH - (CH_2)_7 - COOH$

(2) $CH_3 - CH_2 - CH_2 - CH_2 - CH_2 - CH = CH - CH_2 - CH = CH - (CH_2)_7 - COOH$

(3) $CH_3 - CH_2 - CH = CH - CH_2 - CH = CH - CH_2 - CH = CH - (CH_2)_7 - COOH$

(1) W:9 (octadecenoic acid) oleic acid

(2) W:6 (octadecadienoic acid) linoleic acid

(3) W:3 (octadecatrienoic acid) linolenic acid

Elongation and desaturation of these fatty acids can take place, but the final products formed depend upon the affinity of the W:4, W:5 and W:6 desaturases for

their substrates and competition or inhibition by substrates from the different groups. Oleic acid does undergo desaturation and elongation only in the absence of linoleic and linolenic acids. Also the ratio of (C 20:3 5, 8, 11) eicosatrienoic acid, "by-product" of oleic acid, to (C 20:4 5, 8, 11, 14) arachidonic acid, "by-product" of linoleic acid, is a useful ratio that indicates the essential fatty acid status of the animal (Enser 1984). Products of oleic acid metabolism are increased more in ruminants than in other meat animals, due to the extensive loss of linoleic and linolenic acids in the rumen.

Lipolytic activity, which is a microbial process, in the rumen extends to a wide range of esterified substrates. Dietary lipids are extensively modified in the rumen by hydrolysis of the ester linkages between fatty acids and glycerol and by hydrogenation of unsaturated fatty acids by rumen micro-organisms (Bath and Hill 1967). The rumen displays a great ability to hydrogenate and convert linoleic acid and other polyunsaturated fatty acids of the diet to steoric acid accompanied with smaller quantities of unsaturated positional and geometrical isomers of C18 components (Harfoot 1978).

The biohydrogenation mechanism is complex and still remains a field of investigation. Although it has been established that cell-free ruminal fluid is incapable to initiate any biohydrogenation, the theory of bacterial, protozoal and fine food particles being credited with biohydrogenation properties, still remains questionable. However the final outcome of the dietary lipid changes in the rumen is as follows: Linoleic acid becomes a minor component of the fatty acid profile while stearic acid is increased and becomes the major component (Lennox et al 1968). Long chain unesterified fatty acids are the major lipid class within the digest and some (16%) of the total lipid is found in association with the protozoal population while (4%) is found with the bacterial population (under the form of neutral and phospholipids) (ViViani 1970).

The 30-40g of dietary fatty acids that enter the duodenum of the sheep each day are augmented with daily secretion of 10-15g of biliary lipids (Adams and Heath 1963). The lipid composition of the digesta is markedly altered as it passes the point of entry of the bile/pancreatic duct. An increased proportion of phosphalidylcholine (a phospholipid) occurs and is maintained as the digesta passes through the proximal

jejunum. The acidic conditions in the duodenum (pH:2-3.5) and the proximal jejunum (pH 3.6-4.2) inhibit the activities of the pancreatic phospholipases A1 and A2. Moore and Chistie (1984) assumed that the extremely low pH (2.5) in the proximal duodenum might irreversibly inactivate the pancreatic phospholipase A1.

On the other hand hydrolysis of phospholipids begins at pH=4.7 up to pH=7.6, or when the digesta reaches the mid-jejunum, throughout the distal jejunum. The digesta thus contains high proportion of lysophosphatidylcholine and unsaturated unesterised fatty acids (Leat and Harrison 1969).

In spite of the changes that occur in the lipid composition in the digesta while passing through the small intestine, the major proportion remains with particulate matter, i.e. in ovine jujenal contents, 78% of the total unesterified fatty acids, 70% of the total phosphatidylcholine and 60% of the total lysophosphatidylcholine are absorbed on to the surface of the particulate phase (Lennox et al 1968).

Fatty acids which are released by adipose and other tissues into the blood, are transported bound to albumin and other blood proteins with a small amount

of fatty acid in true solution. The equilibration between blood fatty acids with tissue fatty acids occurs rapidly. The supply of fatty acids to tissue cytoplasmic enzymes is proportional to serum fatty acid concentration (Lindsay 1975). The intestine is the recipient of fatty acids from blood (endogenous) and from the digesta (mainly exogenous). These exogenous and endogenous fatty acids, which are C16 to C18, are exterified to form triglycerides (triacylglycerols), phospholipids and cholesterol esters (Leat and Harrison 1975).

2.5.3.1 Triglycerides

Triglycerides represent a very convenient and highly efficient form of storing fatty acids which constitute a major reservoir source of fuel in animals. Three fatty acids can be stored per triglyceride molecule in anhydrous form in adipose tissue. When nutrient supply fails to meet the energy requirements of tissues, adipose tissue triglycerides are mobilized as plasma free fatty acid, which is used as an energy source by most tissues (Pethick et al 1984).

2.5.3.2 Phospholipids

Phospholipids are mixed esters of fatty acids and phosphoric acid with the alcohols glycerol or sphingosine. They derive their lipid properties from the long chain fatty acid moities but also have a considerable polar character inherited by the ionasation of the phosphate and base groups.

The concentration of phospholipids in muscle and adipose tissues is between 0.5% and 1% of wet tissue whereas in liver it varies from 2 to 3%. Lecithin (Phosphatidylcholine) is the major phospholipid in several tissues, except the brain.

Different phospholipids have different fatty acid compositions. Hornstein and co-workers (1961), found in beef muscle that arachidonic acid is the main polyunsaturated fatty acid in phosphatidyl ethanolamine whereas linoleic acid is the major polyunsaturated component of phosphatidyl choline.

Sphingomyelin is a phospholipid that does not contain glycerol. Sphingomyelin and related compounds, present in membranes, form 10 to 25% of phospholipids of red cell membranes in several species (De Gier and van Deenen 1961). They represent 10 to 25% of the

brain phospholipids but only 5% are present in muscle phospholipids.

2.5.3.3 Cholesterol

Cholesterol is quantitatively an important constituent of the brain, where it may form up to 17% of the dry matter. Cholesterol is present in membranes where the hydrophilic hydroxyl group is allied to the polar end of the phospholipids. Thus the membrane properties seem to be related to the cholesterol: Phospholipid ratio (Gurr and James 1980).

Feeley et al (1972) came to the conclusion that, on the fresh weight basis that adipose and muscle tissues contain similar amounts of cholesterol (mg 1100g); raw lean beef (65) and separable fat (75); lean lamb (70) and separable lamb fat (85); lean pork (60) and separable fat (70).

Cholesteryl-esters are important and responsible for cholesterol transport, by the blood, between tissues. Around 80% of the plasma cholesterol is esterified involving linoleic and oleic fatty acids mainly. Animals can synthesize cholesterol or obtain it from dietary channels. Ruminant diets however rarely

contain more than trace amounts of cholesterol. So this essential lipoprotein compound is synthetised in the mucosal cells of the ruminant small intestine (Scott and Cook 1975). The mechanism of cholesterol esterification in the ruminant enterocyte is still under investigation, but in the rat an enzyme (Acyl CoA : Cholesterolacyltransferase) present in intestinal mucosal cells, catalyses the synthesis of cholesterol esters from cholesterol and fatty acyl CoA derivatives (Haugen and Norum 1976).

The relationship between the content of cholesterol and saturated fatty acids has been intensively studied because hypercholesteroleamia is a contributory factor in atherosclerosis.

2.6 MEAT AS FOOD

2.6.1 Introduction

In western countries, such as Australia, the relationship between diet, nutrition and health is attracting increasing public interest. Epidemiological studies have established a positive correlation between overnutrition (excess intake of energy, fats, salt, sugar and alcohol) and many common diseases of western man (diseases of affluence), due to the association of the distribution of these diseases (occlusive vascular diseases, obesity, diabetes, gallstones, bowel diseases, hypertension and certain cancers) with economic wealth (O'Dea and Sinclair 1983).

Major dietary changes have occurred in the western diet, over the past century. Saturated fat and refined carbohydrate have replaced fibre-rich staples. The main sources of saturated fat, in the western diet are beef, lamb, pork and dairy products.

2.6.2 Meat Consumption in Australia

In 1986, Australians consumed an average of 84.8kg of meat and meat products per capita : bovine meat represented 50.35%, ovine meat 25.23%, porcine meat 19.40% and 5% from offals (Castle 1986).

Since 1980 beef consumption has decreased by 10% while sheep and pork meats have risen by approximately 15%. Baghurst and Syrette (1987) came to the conclusion that meat *per se* remains the main source of protein and micronutrients in the urban Australian diet. It provides only 7.5% of energy and 10-12% of fat and contributes considerably to cholesterol intake, while meat products, or processed meats contain high proportions of fat, energy and salt.

From a purely nutritional point of view, meat is an excellent source of essential amino acids, certain minerals and some vitamins (e.g. B12). Although essential fatty acids and other vitamins are also present, these nutrients would be available from other sources.

The amino-acid composition of fresh meat is composed of nine essential amino acids (isoleucine, leucine, lysine, methionine, cystine, phenylalanine, threonine,

tryptophan and valine, arginine and histidine (essential for infants)) and seven non-essential amino acids (alanine, aspartic and glutamic acids, glycine, proline, serine and tyrosine). The amounts of amino acids not only vary between species but also between specific muscle locations and animal age (Lawrie 1979).

Of the mineral components, potassium is quantitatively the highest, followed by phosphorus. In many respects meat is a valuably important source of iron, as it is in a highly available form and enhances the uptake of iron from vegetables eaten concomitantly (Bender 1975).

Meat is regarded as an important source of vitamins B1 and B2, and also contains one substance not found in a green plant and essential for man's life - cyanocobalamin or vitamin B12. (B12 is available in milk and dairy products) (Tracey 1974).

2.6.3 Animal Fats and Human Health

From a human nutrition viewpoint two types of animal fats have been identified.

2.6.3.1 "Hard" Fat or Storage Fat

"Hard fat or storage fat is composed of triglycerides and is largely saturated. The intake of saturated fats is closely related to the level of cholesterol in the blood stream which in turn has been shown to be closely related to the risk of subsequent coronary heart disease (Hetzel 1983).

2.6.3.2 "Soft" Fat or Structural Fat

"Soft" fat or structural fat is mainly composed of phospholipids. It is an important ingredient of all cell membranes present in the body (muscle, nerve cells, etc.). Structural fat contains high proportions of polyunsaturated fatty acids (PUFA). There are two parent PUFA : C 18:2 W6 (i.e. Omega-6 linoleic acid) and C 18:2 W3 (linolenic acid) which are readily available from plants. Herbivores convert the parent fatty acid of the W6 series to C 20:4 W6 (arachidonic acid) and the parent fatty acid of the W3 series to C 20:5 W3 (eicosapentaence acid) and to C 22:6 W3 (docosahexaenoic acid) by desaturation and elongation. By eating tissues of animal origin (such as red meat) omnivores receive a diet rich in anachidonic acid (C 20:4 W6) and C22:6 W3. No

interconversion between the C:22 fatty acids (W3) and C:20 fatty acids (W6) is possible in the animal organism (Budowski and Crawford 1985).

Arachidonic acid is the major PUFA metabolite of linoleic acid (W6) although man is a poor converter of linoleic acid to arachidonic acid. An adequate supply of this W6 PUFA metabolite has to come from dietary sources of preformed arachidonates (such as meat, offal, eggs, human milk and fish) in order to prevent W6 PUFA deficiency which can affect growth rate, skin condition, lipid transport and reproduction (Sinclair 1985).

On the other hand the W3 PUFA docosahexaenoic acid (C 22:6 W3) is the main metabolite of linolenic acid which is found in high concentration in the grey matter and retinal phospholipids in mammals.

Budowski and Crawford (1985) stated that the main role of W3 PUFA is of modulator of the arachidonic metabolism; by competitive inhibition by linolenic acid of the conversion of linoleic acid to arachidonic acid, thus reducing the amounts of substrate available for prostaglandins (PG) and thromboxane (TX). Excessive production of thromboxane from arachidonic

acid has detrimental effects (fatal outcomes) caused by unrestrained arachidonic metabolim. The eskimos' diet is very rich in fat (more specifically in W3 PUFA) but they have a very low incidence of coronary heart disease. High levels of W3 PUFA have been found in their tissue lipids and reduced levels of W6 PUFA (Sinclair 1985).

Linoleic acid and linolenic acid compete for desaturatin and incorporation, their relative amounts ar important. The ratio W6:W3 is a useful index. In western countries the ratio W6:W3 is of the average 10:1 (Budowski and Crawford 1985). The preponderance of W6 F.A. over the W3 F.A is explained by the increased consumption of linoleic acid - rich vegetable oils. While the ratio W6:W3 in wild animals is ranging from 2:1 to 4:4 (Crawford et al 1969).

In conclusion, due to the fact of growing public awareness of the detrimental effects of diet rich in saturated fat and high ratio W6:W3 on health, the meat and dairy producers need to reverse the criteria for the assessment of meat carcasses and milk by their management practices in order to reduce fat deposition in animals destined for human consumption.

CHAPTER 3. MATERIALS AND METHODS

3.1 Body Composition

Prediction of body composition in vivo was made through the measurement of tritiated water (TOH) space and the estimation of total body water. Twenty four hours prior to administration of (TOH) the experimental animals were taken off feed and water. Each animal was injected intramuscularly with 1.5ml of 100μCi/ml of tritiated water ([3H] H_2O). Blood samples were taken from the jugular vein 6 hours post injection and these were analysed for tritium content. However in order to assess residues from previous (TOH) injections, blood samples were also taken prior to new (TOH) administration.

3.1.1 Extraction of Tritiated Water

Extraction of tritiated water from blood samples was carried by lyophilization of the samples in experiment I and by azeotropic distillation of the samples in experiment II.

3.1.1.1 Lyophilization Method

Labelled water was removed from plasma by rapid vacuum sublimation by use of the apparatus described by Vaughan and Boling (1961). Two to three ml of blood was frozen in a Thungerg tube by immersion in liquid nitrogen and the unit was evacuated while being connected to a high vacuum pump (pressure around 25u). The thunberg closure was then made and the apparatus disconnected from the vacuum pump. The collection tube was then dipped into liquid nitrogen contained in a thermo (vacuum) flask overnight. The tubes were transferred to a rack allowing the formed ice to thaw, after release of the vacuum. The water was transferred to appropriately labelled tubes prior to counting.

3.1.1.2 Azeotropic Distillation Method

Tritiated water was extracted by distillation (this method had been adapted from Dewar's and McDonald's (1961) technique) using the Dean and Starke apparatus, constructed with a graduated receiver of approximately 5ml and stop-cock to run off the heavier

aqueous layer after distillation. Approximately 10ml of whole blood was mixed with 40 to 50ml of Jet A1 aviation fuel (kerosine; with boiling point ranging from 160-240°C) in a 200ml round-bottom flask. The flask was put on a heating mantle (Electrothermal/type EME 6 02501CE). The quantity of fuel used was sufficient to allow continuous circulation of solvent within the apparatus (six samples were run simultaneously). The mixture was brought to a vigorous boil for 20 minutes or when separation was completed. The water fraction was transferred to a stoppered glass bottle and a small quantity of paraffin wax (about $1cm^2$) was added to the extract. The bottles were immersed in a water bath (60°C) to melt the wax and absorb any solvent residues. The azeotropic distillation technique allowed processing of a larger number of blood samples (70 to 80 samples/day) due to its simplicity while the lyophilisation procedure allowed only the processing of some 12-15 samples a day (some needing repeated handling if the vacuum had been lost).

3.1.2 Tritium Assay

Tritium concentration was determined by measuring the radioactivity of the extracted water. This was determined in a liquid scintillation spectrometer (LKB.1215 Rackbeta II counter; Wallac OY; Finland).

To 0.5ml of extracted water was added 4.5ml of premixed scintillation cocktail (Insta-Gel^{R}; Packard Instrument CO., USA). Each vial was counted for a minimum of 20,000 counts on separate occasions. Blank samples and triplicate samples of a standard solution (25mμCi/ml) were made up with every batch.

In order to compare the azeotropic distillation method with the rapid vacuum sublimation method duplicate blood samples were taken from sheep injected with tritiated water as described earlier. Also blood samples were taken from sheep containing no isotope but specific measures of [^{3}H] H O (1 to 50 n Ci/ml) were added to the blood in the laboratory. Water extractation was carried by both techniques.

Determination of total body water of the injected animals by both techniques appeared to produce similar results and the difference was not statistically significant ($P<0.05$) as shown in Table 2.

Specific activities of extracts of samples containing different concentrations of tritiated water are shown in Figure 5. Results obtained by either extracting techniques appeared to be very similar over the range of ^{3}H. Although the regression lines differ

statistically ($P<0.05$) although at the concentration range used in body water estimation (5 to 10 nCi/ml), the difference was not significant ($P>0.05$).

The slightly lower values recorded at high concentrations may have been attributed to the fact that small quantities of tritiated water were adhering to condenser wall and not reaching the collecting vessel as the effect was emphasised by high concentration.

The azeotropic distillation method proved to be as effective in separating labelled water from biological fluid as the rapid vacuum sublimation method. However it should be stressed that the distillation technique was by far, favoured in this study due to the fact that the procedure was rapid and induces minimal isotope fractionation. In contrast the sublimation method required several high vacuum pieces of apparatus and all of which might be the subject of loss of vacuum during separation process. (A paper discussing the two methods is in preparation - Cuthbertson, A.Z.; Dighton, J.C. and Siebert, B.D. : J. App. Radiation and Isotopes).

3.1.3 Predicition of Body Composition

The multiple regression equations of Searle (1970) were used to predict the weight of some of the body components a sheep used in the studies. These were:

(i) Total body water (kg) = 0.01 + 0.92X

(ii) Fat (kg) = 0.16-1.14X + 0.95Y

(iii) Lean body mass (kg) = -0.46 + 1.24X

(iv) Energy (MJ) = (-0.30-8.87X + 8.54Y)4.184

Where X = TOH space (kg)

Y = Live weight (kg)

3.2 Feed Intake

A number of techniques are available to estimate the nutrient intake of grazing animals. The purpose of the present study was to investigate:

(i) in the first experiment, the effect of breed on voluntary feed consumption and efficiency of feed conversion; and

(ii) in the second experiment the effect of anabolic agents on feed intake and feed conversion efficiency.

Voluntary feed consumption from grazing sheep was estimated indirectly from chromium dosing.

3.2.1 Estimation of Faecal Dry Matter Output of Grazing Sheep

Experimental animals were individually fitted with a controlled release intraruminal device (CRD). This device comprised a spring driven system consisting of cylindrical plastic barrel (15 mm diameter) and 9-10cm long. It contains a core of dissoluble matrix composed of chromic oxide (5g) an insoluble marker mixed with sucrose mono-stearate (50:50, W/W); used as a carrier agent; the mixture was then compressed at 2.4 tonnes in a 14.5mm diameter steel die (Laby et al 1984). The precise release rate of CRD was known for each batch.

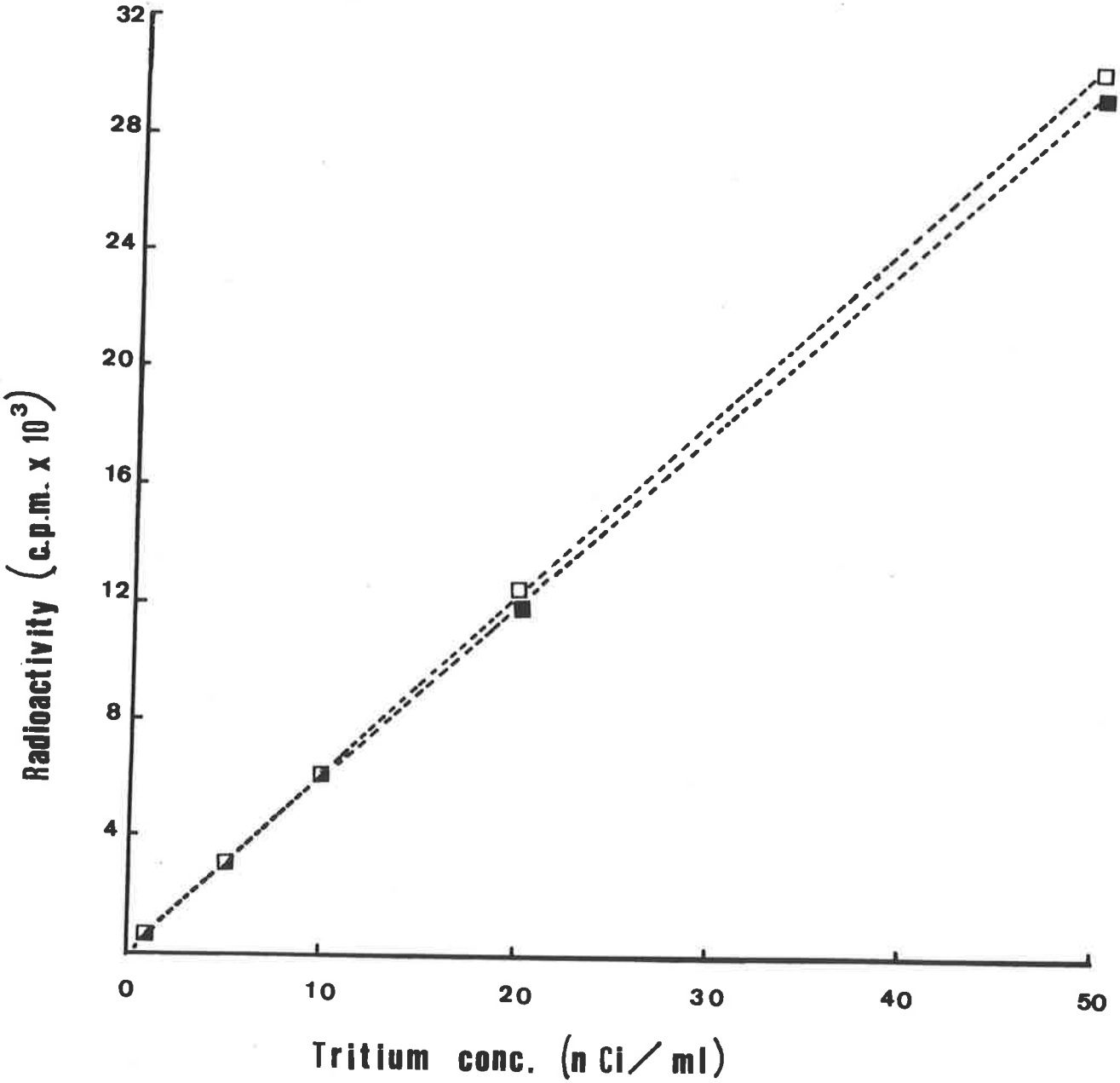
TABLE 2

Method	Total Body Water (l)	Total Body Water (ml/kgL.Wt)
Azeotropic Distillation	22.95 ± 0.59	52.0 ± 2.2
Lyophillisation	23.30 ± 0.44	52.8 ± 1.7
Probability of Differnece	N.S.	N.S.

MEAN VALUES OF TOTAL BODY WATER OF SHEEP DETERMINED BY DILUTION OF TRITIATED WATER EXTRACTED BY EITHER AZEOTROPIC DISTILLATIOR OR LYOPHILISATION

FIGURE 5

RELATIONSHIP OF THE MEASURED COUNTS OF RADIOACTIVITY OF VARIOUS CONCENTRATIONS OF TRITIUM WHEN EXTRACTED BY DISTILLATION (■) OR SUBLIMATION (⧈) TECHNIQUE


32
28
24
20
16
12
8
4
0
10
20
30
40
50
Radioactivity (c.p.m. x 10³)
Tritium conc. (n Ci / ml)

3.2.1.1 Measured Dry Matter Faecal Outputs Versus Estimated Faecal Dry Matter Outputs

A preliminary experiment was conducted with housed sheep fitted with CRD in order to establish the relationship between estimated and measured dry matter faecal outputs.

Six sheep were individually penned and allocated to three groups of two (pairs). Each pair received one of the three formulated diets:

(i) Diet 1 : Lucerne/oat (50/50);

(ii) Diet 2 : Lucerne/oat/oaten hay/wheaten hay (25/25/25/25);

(ii) Diet 3 : Oaten hay/wheaten hay (50/50).

After four weeks each pair received one of the two remaining diets.

Animals	1-4 weeks	5-8 weeks
Pair 1	Diet 1	Diet 2
Pair 2	Diet 2	Diet 3
Pair 3	Diet 3	Diet 1

Each sheep was dosed with a CRD and a harness equipped with removable plastic bag.

Complete faeces collections were carried out daily and they were then oven dried (80oC) and weighed. Subsamples of faeces were put aside for chromium oxide analysis. Feed intake was recorded daily. The findings of the experiment are reported in Table 3.

The regression analysis showed a very high correlation ($r=0.968$) existed betweeen the measured and estimated faecal outputs. No siginficant difference occurred ($P<0.05$).

The regression line is shown in Figure 6 and the equation was as follows:

$$Y = 1.088 x - 11.2$$

Where Y = estimated faecal dry matter output
X = measured faecal dry matter output

From the equation, the correction or (adjusting) coefficient was:

$$M = 0.954E^*$$

Where M = measured

E = estimated

* This correcting coefficient was used in adjusting dry matter faecal output estimated from CRD.

3.2.1.2 Deterimination of Chromium in Faeces Samples

Dried faeces samples were finely ground and put in plastic jars appropriately labelled. The procedure of Williams et al (1962) was followed:

. One gram of dried ground sample was placed in a 50ml crucible and ashed at 600°C for 3 hours (in duplicate samples);

. 3ml of phosphoric acid - manganese sulphate solution (30ml of 10%, w/v, $MnSo_4$, 4 H_20 solution in 1.1 of 85% Phosphoric acid) and 4ml of 4.5% w/v, potassium bromate solution were added to a cooled crucible. The crucible was covered with a wath-glass and digested on a preheated hot plate for 5-7 min. or when effervescence stopped and a purple colour appeared.

TABLE 3

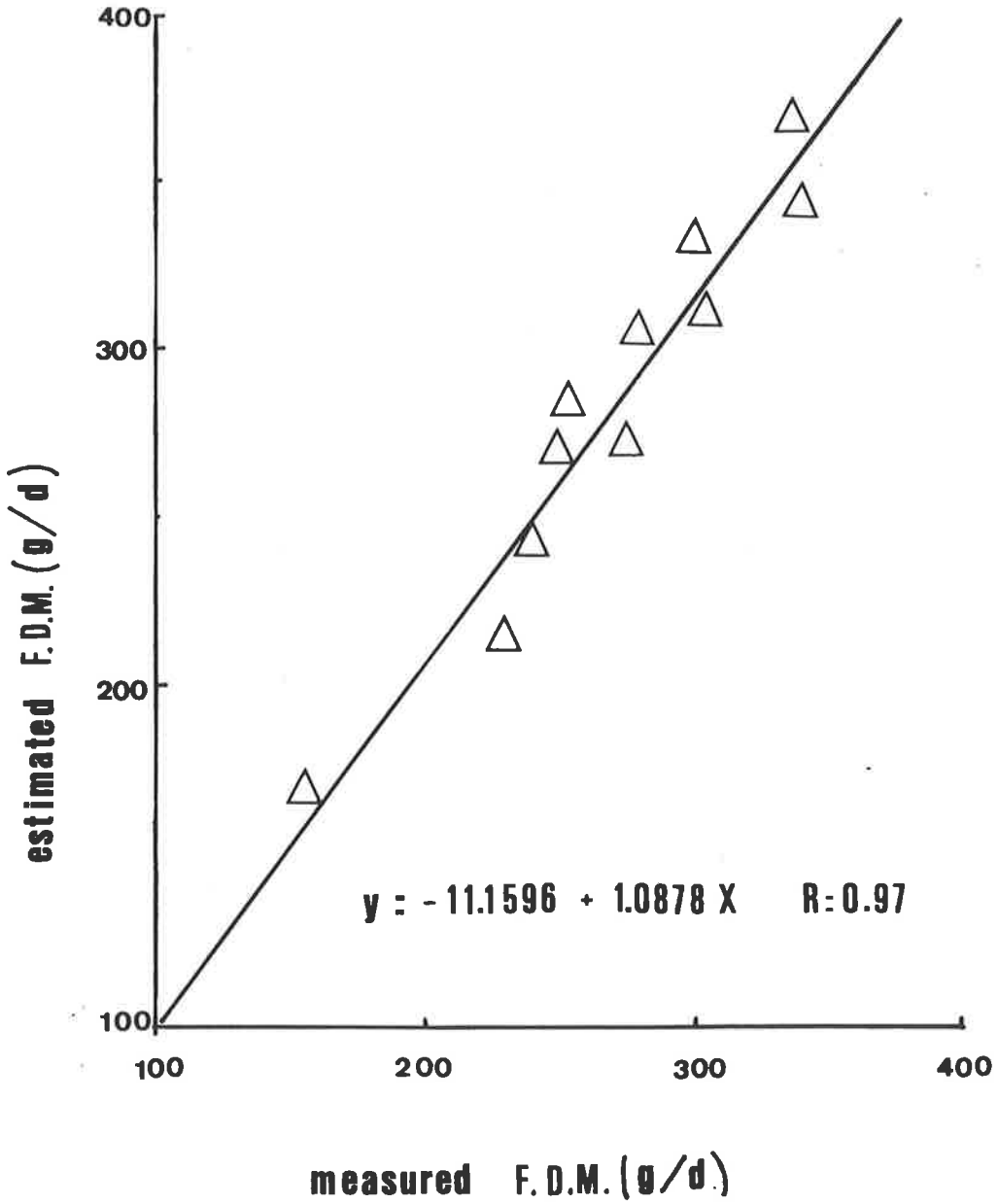
RELATIONSHIP BETWEEN ESTIMATED AND MEASURED FAECAL DRY MATTER OUTPUTS OF SHEEP FITTED WITH CHRONIC OXYDE SLOW RELEASE DEVICE AND INDIVIDUALLY PEN FED

PART I DIET	SHEEP NO.	DRY MATTER INTAKE (g/DAY)	D.M.* DIGESTIBILITY (%)	FAECAL DRY MATTER MEASURED (g/DAY)	FAECAL DRY MATTER ESTIMATED (g/DAY)
1	162	799	71.1	229	213
	168	810		236	242
2	165	810	62.25	338	341
	166	810		274	271
3	164	780	62.05	302	310
	167	808		299	330
PART II DIET					
2	162	810	66.3	280	303
	168	770		252	283
1	164	582	70.8	159	167
	167	810		251	268
3	165	810	60.2	337	366
	166	770		292	-

* Dry matter Digestibility (%) = DDM% = $\frac{\text{Intake - Faeces}}{\text{Intake}} \times 100$

FIGURE 6

RELATIONSHIP BETWEEN ESTIMATED FAECAL DRY MATTER OUTPUT AND MEASURED FAECAL DRY MATTER OUTPUT


400
300
200
100
estimated F.D.M. (g/d)
y = -11.1596 + 1.0878 X R=0.97
100
200
300
400
measured F.D.M. (g/d)

After the mixture cooled it was transferred to a 200ml volumetric flask and diluted with distilled water. 25ml of calcium chloride solution (containing 4000 p.p.m.of calcium) were added to the flask, made to volume with distilled water and mixed thoroughly. The mixture was then allowed to stand overnight allowing suspended material to settle. It was filtered prior to analysis.

A set of standards was made up, containing 0-70 p.p.m. of chromium, 500 p.p.m. of calcium, 50 p.p.m. of silica and phosphoric acid, manganese sulphate and potassium bromate at the same concentration as used in the digestion of samples.

The chromium concentration of samples was determined by atomic absorption spectrometer fitted with a chromium hollow cathode tube. (Varian Ltd Model AA1275 - Wave length 425u, slit width 4mm).

The concentration of chromium was then calculated per gram of dry matter faecal output. Knowing the CRD release rate, the estimation of dry matter faecal output/per day was calculated as follows:

$$\text{Dry matter faecal output (g/day)} = \frac{\text{CRD release rate}}{\text{[Cr]/g of DM Faecal output}}$$

Dry matter digestibility was needed to estimate voluntary intake of grazing animals. So in experiment 1, two lambs from Dorset x Romney

Merino group and two lambs from South Australian group were taken randomly and were surgically fitted with oesophageal fistula.

Fistulated animals (kept off grazing for several hours) were sampled after 30 minutes grazing. Extrusa collected from fistulated animals was lightly squeezed in a muslin and put in plastic bags which were immersed in liquid nitrogen. To prevent browning the extrusa samples were freeze dried, then finely ground and stored in jars prior to "In Vitro" digestibiity analysis.

3.2.3 In Vitro Dry Matter Digestibility Analysis

The in vitro digestibility method of Tilley and Terry (1963) was used. This technique involves first, a 48 hour incubation with rumen micro-organisms and buffer and, second, a hydrochloric acid-pepsin digestion. The amount of dry matter disappearing after both stages is considered to have been "digested".

3.2.3.1 Procedure

0.5g was placed in numbered centrifuge tubes (in duplicate) and the weight was recorded, two empty tubes were set aside as blanks. The tubes were held in incubation baths. A mixture of 40ml of buffer solution and 10ml of strained rumen liquor was added to each tube; using a dispenser gassing CO_2 in each tube to reduce pH from 8.3 to 7.0, then stoppered and incubated at 39°C for 48 hours. The tubes were gently shaken twice a day during the first day, and three times during the second.

After 48 hours incubation, the tubes were swirled and the stoppers removed, the pH checked (less than 7.0). To each tube 50ml pepsin solution was added and the tube returned to the incubator.

Periodically the tubes were shaken gently. After 48 hours the tubes were centrifuged for 8 to 10 minutes at 3000 r.p.m., the residues were transferred to preweighted crucibles and oven dried at 104°C for at least 24 hours. The *in vitro* dry matter digestibility was calculated from the results and subseqently the *in vivo* digestibility values were determined from reference to standards. The *in vitro* values for

samples taken from oesophageal fistula from sheep at three sampling times are shown in Table 4.

Voluntary feed intake was calculated as follows:

Voluntary feed consumption = Faecal dry matter
(g/day) 1- (Dry matter digestibility

3.3 Fatty Acid Extraction From Muscle Samples

Muscle sampling on live sheep was carried out by a technique developed by Siebert and Cuthbertson for the purpose of assessing the intramuscular fatty acids.

The sampling procedure was carried out by the use of a custom-made stainless steel biopsy needle similar to that used in human medicine.

3.3.1 Sampling Procedure

Wool near the *longissimus dorsi* area was removed by clipping and a patch cleaned with Zepherin solution. An injection of lignocaine (2-3ml) was given locally and an incision of about 1.5cm made with a scalpel. The biopsy needle was then inserted into the *L.dorse* muscle and a sample recovered from the hollow part of the needle.

The sample was placed in a glass vial with a few ml of distilled water and the vial submersed in liquid nitrogen. The wound was cleaned and sprinkled with an antibacterial powder and an antiseptic cream. The animal was then returned back to pen or paddock. No infections were noted. The samples were stored at -80oC.

3.3.2 Procedure of Fatty Acid Extraction

Samples were processed by a modified version of Folch's and co-workers' method (1957) or chloroform methanol (2:1 w/w) extraction. Fatty acids* were prepared from thin layer chromatography and the methylesters obtained were analysed by gas-liquid chromatography with a Hewlett Packard 5890 gas chromatography equipped with a flame ionisation detector. A glass column packed with SP2310 (5% on 100/120 Chromasorb WAW, Supelco) was used and the separation was carried out over the programmed temperature range of 150-230oC.

* Polyunsaturated fatty acids reported in this thesis are shown as W-3 and W-6, representing the omega-3 and omega-6 convention terminology.

TABLE 4

Breeds	Aug/Sept Phase	Oct/Nov Phase	Dec/Jan Phase
S.A. Merino samples	71.72%	63%	54%
Dorset x Romney Merion samples	70.58%	64%	55%
Mean *in vivo* matter Digestibility (%)	71.15%	63.5%	54.5%

DRY MATTER DIGESTIBILITY OF PASTURE SAMPLES TAKEN FROM OESOPHAGEAL FISTULATED SHEEP

EXPERIMENT 1 : EFFECT OF BREED TYPE ON GROWTH AND LEAN MEAT PRODUCTION IN GRAZING LAMBS

4.1 INTRODUCTION

The growth patterns and composition of the bodies of mammals differ within a genus so that wild species (e.g. deer, goat) differ from domestic species such as sheep and cattle, not only in their size but in the amount of fat they contain (Crawford 1975 and Panaretto 1963). These differences are not great within a species, but they do occur, so that beef cattle for example are composed differently to dairy cattle. Still further some producers believe within breed differences are more important than between breed differences (Cundiff 1986).

In general the differences between types (breeds) are associated with the stage of maturity. Animals that mature the earliest in terms of body development, also reach sexual maturity the earliest and contain the most fat. Earlier maturing animals do not attain the same body weight (or height) as later maturing animals

which are at a particular age considerably leaner (Reid et al 1968). Studies in sheep in Australia, particularly those of Searle and Graham (1972) have recorded similar differences between small sheep (Camden Merinos) and larger cross breeds. In detailed studies of body composition from birth to maturity, growth was divided in four phases with fat deposition occurring at a maximum rate in the final phase, although the point that fat deposition commenced in the different types studied did not differ markedly (e,g, 25kg to 30kg).

As mentioned above, fat deposition in animals does not only differ between genotypes, selection studies within a breed of chicken have found that growth and fatness differed in animals that were selected for different reasons (Pym and Solvyns 1979). Animals selected for weight gain, food consumption or efficiency of feed conversion into liveweight gain, all gained more weight than unselected animals. Those selected for food consumption were the fattest while those selected for efficiency were the leanest.

Thus, in animal research either within or between types or breed, there exist considerable genetic

variation in the ability to grow and lay down fat. Leanness is best associated with growth and late maturity on one hand and the ability to efficiently convert feed to body tissue on the other.

The following experiment was designed to study in grazing sheep the effect of breed types on growth, body composition (total body water, fat, lean body mass and energy), feed intake and the efficiency of converting feed to live weight and lean body.

4.2 EXPERIMENTAL PROCEDURE

4.2.1 Site

The experiment was carried out at the CSIRO "Glenthorne" property at O'Halloran Hill, S.A., on the outskirts of Adelaide. The sheep were raised on a grass dominated pasture.

4.2.2 Animals

Four breeds of sheep were used in the experiment. They were:

(i) South Australian Merino straight breed (SA-M);

(ii) Dorset x (Romney x Merino) cross bred (DXRM);

(iii) Peppin Merino straight breed (P-M);

(iv) Suffolk x Merino first cross bred (SXM).

Ten wether lambs of each breed were purchased at weaning from four different properties in South Australia. The ages were matched as closely as possible. Six animals of each breed were raised together and kept as one flock.

4.2.3 Measurements

Body growth, body composition and feed consumption measurements were made on each animal over a period of 4 months from winter/spring through to summer, while the animals grazed the pastures referred to above. Body growth was measured by weighing individual lambs at approximately 4 weeks to the nearest 0.5kg and body composition was determined by measuring the tritiated water space and using the multiple regression equations of Searle (1970) (see Chapter 3).

Feed consumption was measured over three periods in grazing animals over 7 days following body weight and body composition measurements in August, October and end of November. Feed intake measurements were estimated by use of chromic oxide as a marker (see chapter 3). Individual animals from each breed were fitted with chromic oxide slow release capsules. Faeces were collected with the use of a collection harness. Chromic oxide concentration was determined in faeces by atomic absorption spectrometry (see Chapter 3). The value of digestibility obtained from an in vitro measurement on extrusa from oesophageal fistulated animals, enabled the calculation of the dry matter intake to be made for each animal.

4.3. RESULTS

4.3.1 Live Weight

The growth of the four groups of sheep between August and January is shown in Table 5 and Figure 7a.

The four breeds of sheep increased in weight until December, but lost weight between December and January. In August the live weight of Peppin Merino and Dorset cross bred groups differed significantly

TABLE 5

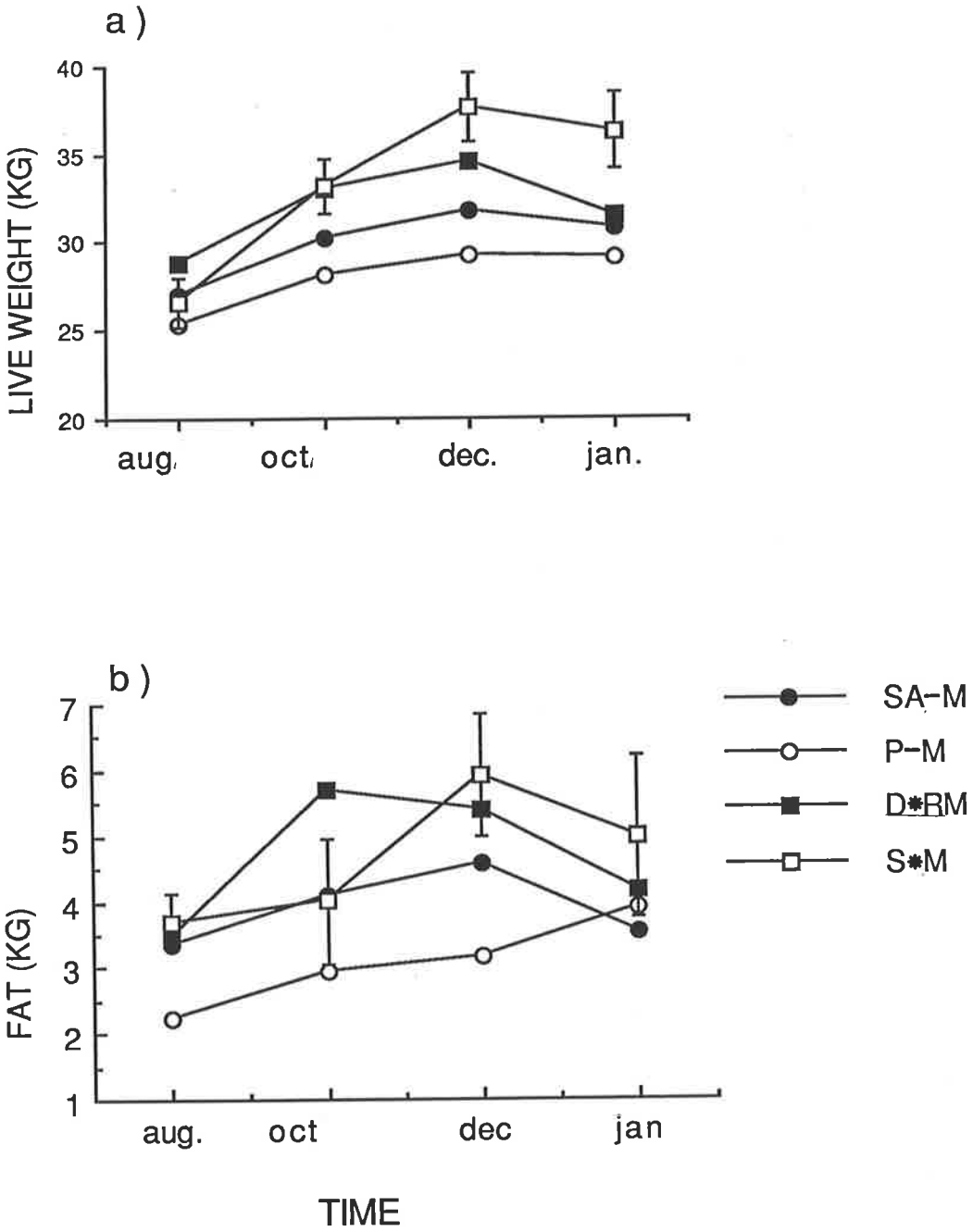
LIVEWEIGHT AND BODY COMPOSITION OF THE DIFFERENT BREEDS

	AUGUST				OCTOBER				DECEMBER				JANUARY			
	LW[a]	LBM[b]	FAT[c]	ENERGY[d]	LW	LBM	FAT	ENERGY	LW	LBM	FAT	ENERGY	LW	LBM	FAT	ENERGY
SA-M	27.02	22.66	3.33	225.51	30.14	25.37	4.10	280	31.75	26.29	4.57	288.7	30.8	27.82	3.52	256.48
P-M	25.28	23.86	2.23	189.53	28.17	24.58	2.94	220	29.17	25.51	3.18	243.92	29.13	27.0	3.90	250
D*RM	28.78	22.51	3.46	229.7	33.05	26.92	5.70	334.72	34.52	26.53	5.41	316.31	31.52	27.12	4.16	282.67
S*M	26.58	22.27	3.70	237.23	33.16	28.37	4.01	277.52	37.61	30.14	5.93	333.04	36.27	30.62	5.0	292.46
(P<0.05)	*	*	**	*	*	*	*	*	*	*	*	*	*	*	*	N.S.
SED	1.41	0.482	0.44	14.43	1.56	1.04	0.95	31.12	1.97	1.01	0.934	30.41	2.14	1.342	1.23	40.16

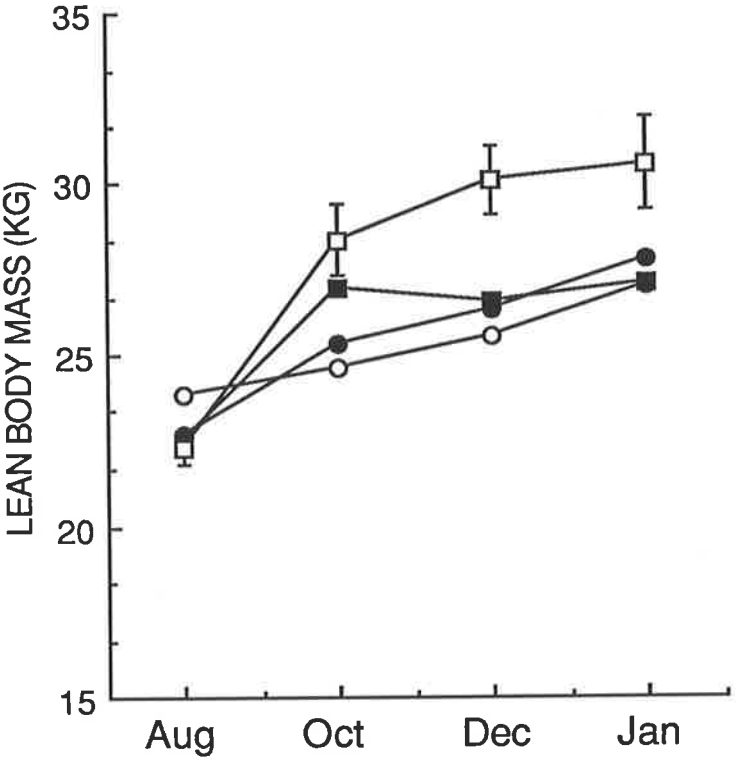
a) Liveweight (kg)
b) Lean Body Mass (kg)
c) Fat (kg)
d) Energy (MJ)

FIGURE 7

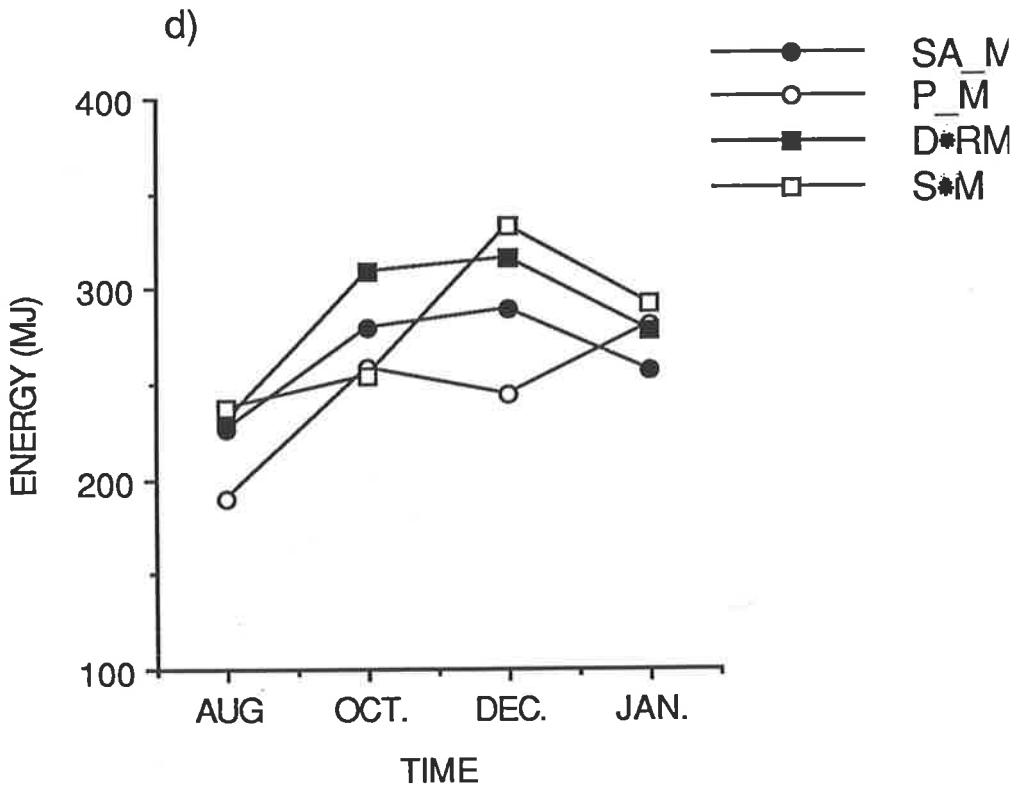
LIVE WEIGHT AND BODY COMPOSITION OF SOUTH AUSTRALIAN MERINO, PEPPIN MERINO, DORSET CROSS AND SUFFOLK CROSS ANIMALS, a) LIVE WEIGHT (kg); b) FAT (kg); c) LEAN BODY MASS, AND d) ENERGY (MJ)


a)
LIVE WEIGHT (KG)
40
35
30
25
20
aug.
oct.
dec.
jan.
b)
FAT (KG)
7
6
5
4
3
2
1
aug.
oct
dec
jan
TIME
SA-M
P-M
D*BM
S*M

C)


35
30
25
20
15
LEAN BODY MASS (KG)
Aug
Oct
Dec
Jan

d)


400
300
200
100
ENERGY (MJ)
AUG
OCT.
DEC.
JAN.
TIME
SA_M
P_M
D*RM
S*M

($P<0.05$). while no difference was recorded between the other breeds. Between August and October the Suffolk cross breds increased live weight by 25% followed by the Dorset cross breds by 15% and 12% for the two Merino groups. There was a significant difference ($P<0.05$) between the growth rate of breeds (except S.A. Merino v Peppin Merino). From October to December the Suffolk cross breds increased their live weight by 13% and were significantly heavier than each of the other breeds ($P<0.05$). The remaining breeds did not differ significantly in live weight in October, having increased their growth rate by about 5%.

Between December and January over summer all breeds lost weight due to the poor nutritive value of the pasture (DM digestibility - 54%). The Peppin Merino group lost the least weight (<1%), the S.A. Merino and Suffolk cross breds lost 3%, while the Dorset cross breds lost 9%. Both Merino strains did not differ significantly, nor did the S.A. Merino and Dorset cross ($P>0.05$). The Suffolk cross were significantly ($P<0.05$) heavier than all three other breeds.

4.3.2 Body Composition

Lean body mass, fat and energy data are shown in Table 5 and in Figures 7b, 7c and 7d respectively. The estimated amounts of total extractable fat, lean body mass and energy in the body varied with body weight and breeds.

In August the Peppin Merino group contained significantly less fat and a significantly greater lean body mass than the other breeds ($P<0.05$). In October the Suffolk cross breds had a lean body mass 11% greater lean body mass than that of the three remaining breeds ($P<0.05$). In December the Suffolk cross lean body mass was 18% heavier than the lean body mass of Peppin Merino group and 14% higher from the lean body mass of S.A. Merino and Dorset cross breds ($P<0.05$). No difference was observed between the remaining breeds. In January the lean body mass of the two Merino and Dorset cross groups averaged 27.3kg ($P>0.05$). The Suffolk cross animals however recorded a lean body mass 12% higher than the other breeds ($P<0.05$).

The amount of fat and energy of the animals varied with body weight. In August, fat represented on average 12% of body weight for S.A. Merino and Dorset

cross groups, 14% for Suffolk cross and about 9% for Peppin Merino lambs ($P<0.05$). In October the fat content of Dorset cross breds had markedly increased and was 28% higher than the fat of S.A. Merino and Suffolk cross breds and 48% higher than the fat content of Peppin Merino groups ($P<0.05$).

Between October and December all breeds increased their fat content. The two cross bred groups had more fat (about 5.7kg) and were 20% and 44% fatter than S.A. Merino and Peppin Merino groups respectively ($P<0.05$). Between December and January only the Peppin Merino group managed to increase its fat content (by 18%), while the remaining breeds depleted their fat reserves by 22% for the S.A. Merino and Dorset cross animals and by 16% for the Suffolk cross animals ($P<0.05$).

The trend of body energy data appeared to be similar to body fat results. In August the mean energy content was about 230MJ for all breeds except for Peppin Merino group which was significantly less ($P<0.05$). Between August and October the Dorset cross breds increased its energy content by 32% and were significantly greater than the other breeds ($P<0.05$), S.A. Merino animals increased their energy by 20% and the two remaining groups by about 14% ($P>0.05$).

In December the energy content of Suffolk cross breds increased by near 17% but did not differ from the energy increase of the Peppin Merino group (10%) ($P>0.05$). The increase of the S.A. Merino was 3%, whereas the Dorset cross breds recorded a loss of energy of the order of 0.5%. These two latter breeds did differ from the Suffolk cross and Peppin Merino breeds ($P<0.05$).

As fat content declined in January, for S.A. Merino, Dorset and Suffolk cross breds so did their energy content, by about a mean value of 10% ($P>0.05$). Peppin Merinos did increase their energy content by 3% but were not significantly different from the other breeds ($P>0.05$).

4.4 FEED INTAKE AND EFFICIENCY OF FEED CONVERSION

4.4.1 Voluntary Feed Intake and Metabolizable Energy Intake

Voluntary feed intake and metabolizable energy intake was estimated in August (Period 1), October (Period 2) and the end of November (Period 3). Voluntary feed intake and metabolizable energy intake of the 4 breed groups for period 1, 2 and 3 are shown in Table 6 and

summarised in Figure 8a and 8b. Feed intake was fairly constant with an average intake of 839g/day for period 1 and 763g/day for period 2 and no difference between breeds within each period was observed ($P>0.05$). However in period 3 Suffolk cross animals ate significantly more feed than S.A. Merino and Peppin Merino groups ($P<0.05$). The voluntary feed intake of Dorset cross lambs was not different from the other breeds ($P>0.05$).

Metabolizable energy intake of all four breed groups declined with time. The mean values of the four breeds for periods 1, 2 and 3 were 8.60, 6.94 and 6.62MJ/day respectively. This decline was mainly due to the fall in digestibility of the pasture (71%, 63% and 54%). Since dry matter intake was similar for all three periods, indeed it was greater in period 3 than in period 1. The difference in metabolizable energy intake between breed groups however was due to feed intake difference and varied to the same extent.

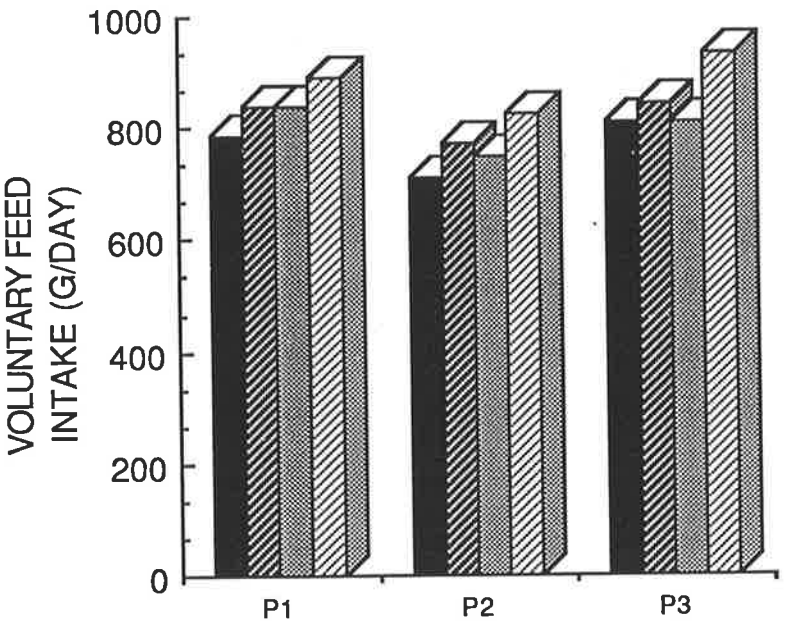
4.4.2 Efficiencies of Feed Conversion

Table 6 shows the efficiences of feed conversion expressed in terms of liveweight growth, lean tissue and energy gain respectively (see also Figure 9a, b and c).

FIGURE 8

VOLUNTARY FEED INTAKE OF THE FOUR BREEDS OVER THREE EXPERIMENTAL PERIODS, a) VOLUNTARY FEED INTAKE (g/DAY), AND b) METABOLIZABLE ENERGY INTAKE (MJ/DAY)

a)


1000
800
600
400
200
0
VOLUNTARY FEED INTAKE (G/DAY)
P1
P2
P3

b)

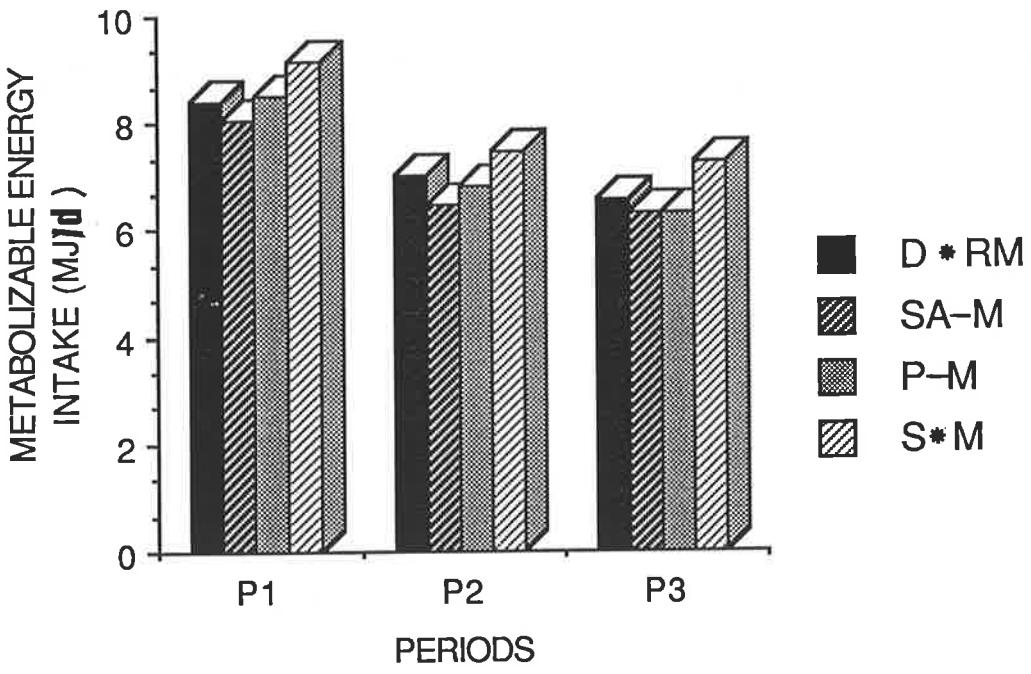

10
8
6
4
2
0
METABOLIZABLE ENERGY INTAKE (MJ/d)
P1
P2
P3
PERIODS
D * RM
SA–M
P–M
S*M

TABLE 6

VOLUNTARY FEED INTAKE AND EFFICIENCIES OF FEED CONVERSION

	AUGUST / PHASE (P1)					NOVEMB/PHASE (P2)					DECEMBER / PHASE (P3)				
BREEDS	(1) VFI	(2) MEI	(3) EFC(1)	(4) EFC(2)	(5) GE	VFI	MEI	EFC(1)	EFC(2)	GE	VFI	MEI	EFC(1)	EFC(2)	GE
SA-M	788	8.02	9.0	9.8	19.27	711	6.46	6.60	3.76	3.80	810	6.31	-2.72	4.07	-11.11
P-M	837	8.53	9.97	2.40	14.64	749	6.80	3.71	3.60	10.16	811	6.31	-0.10	4.08	-1.27
D•RM	838	8.39	14.97	15.53	37.16	772	7.02	5.55	-1.45	-756	845	6.58	-8.03	1.54	-11.18
S•M	893	9.14	21.40	20.85	12.81	822	7.47	15.56	6.11	21.27	931	7.24	-3.14	1.12	-12.21
P{0.01}	N.S.	N.S.	*	*	*	N.S.	N.S.	*	*	*	*	*	*	*	*
{0.05}															
LSD	149.00	1.55	4.9	3.00	8.34	128.15	1.15	1.19	0.60	1.62	94.30	0.736	0.493	0.37	1.06

(1) Volutary Feed Intake (DMg/day)
(2) Metabolizable Energy Intake (MJ/day)
(3) Efficiency of Feed Conversion into Growth ($\frac{DWG}{VFI} \times 100$)
(4) Efficiency of Feed Conversion into Lean Tissue ($\frac{\text{Lean Gain}}{VFI} \times 100$)
(5) Gross Efficiency ($\frac{ME\ Gain}{MEI} \times 100$)

4.4.2.1 Efficiency of Feed Conversion into Liveweight Gain

In period 1, the two Merino groups recorded similar efficiency coefficients (approx. 9%) and were not significantly different ($P>0.05$). The Dorset cross lambs had an efficiency of 14.9%. They were not significantly different from Peppin Merino group but differed significantly to the S.A. Merino group ($P<0.05$). The Suffolk Merino lambs appeared to be the most efficient feed converters, they converted 6.5% and 11.9% more food into live weight than Dorset cross and the two Merino groups respectively ($P<0.05$).

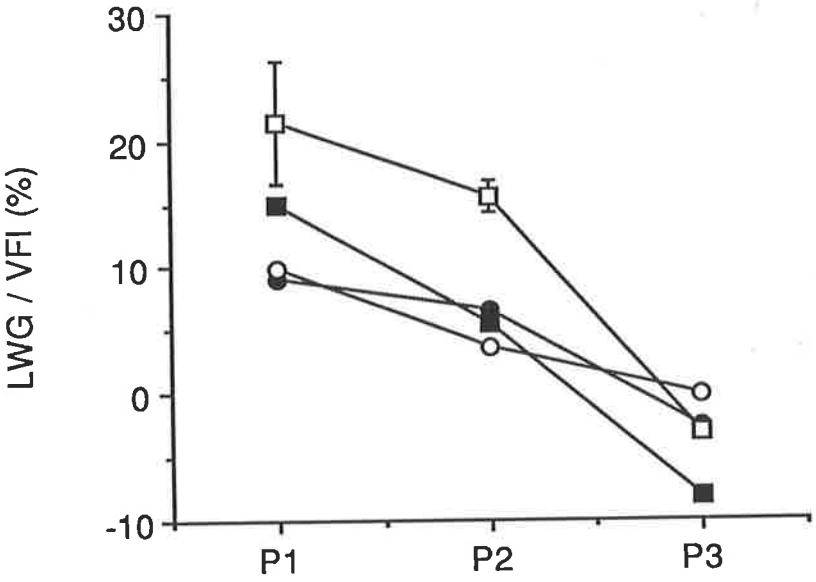
In period 2 efficiency coefficients declined in all breeds. The lowest value was recorded with Peppin Merino group and was significantly different from the other breeds ($P<0.05$). The best feed convertor was again Suffolk Merino breed (despite a 6.0% decline from the previous phase) and was significantly different ($P<0.05$). S.A. Merino and Dorset cross groups showed an average efficiency of 6.0% ($P>0.05$).

In the final period (late November) all breeds recorded negative efficiencies (due to negative liveweight gain) despite a fairly constant feed intake. Dorset cross lambs showed the lowest conversion coefficients and their interaction with the

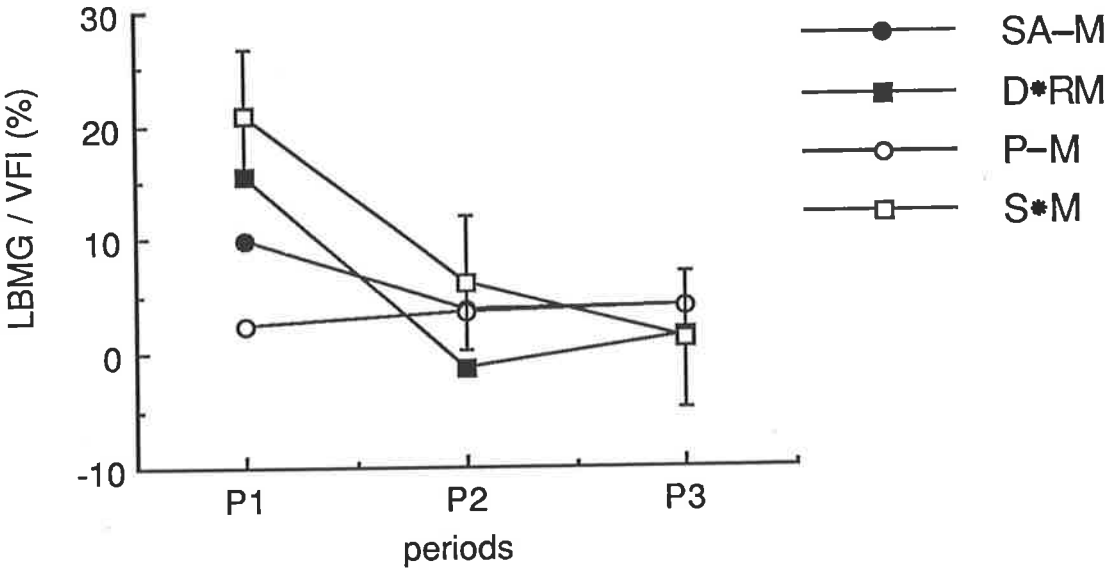
FIGURE 9

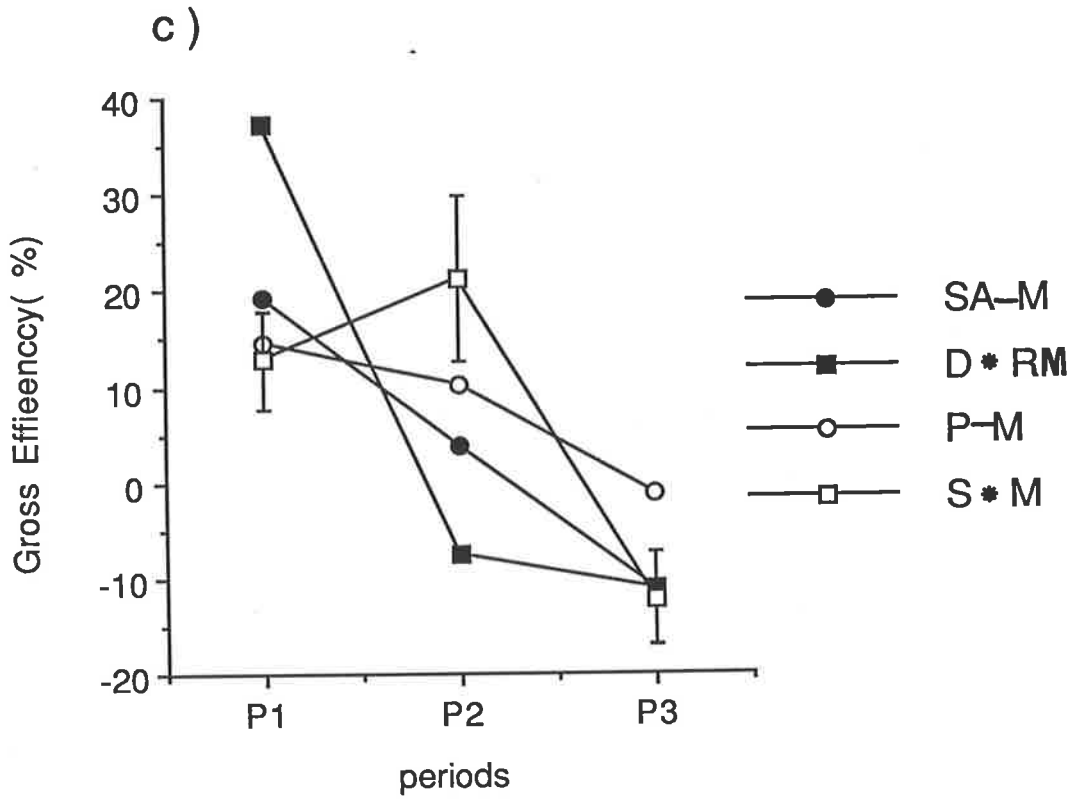
EFFICIENCY OF FEED CONVERSION, a) LIVEWEIGHT GAIN/FEED INTAKE; b) LEAN BODY MASS GAIN/FEED INTAKE, AND c) GROSS EFFICIENCY (ME GAIN/ME INTAKE)

a)


30
20
10
0
-10
LWG / VFI (%)
P1
P2
P3

b)


30
20
10
0
-10
LBMG / VFI (%)
P1
P2
P3
periods
SA–M
D*RM
P–M
S*M


c)
40
30
20
10
0
-10
-20
Gross Effieenccy(%)
P1
P2
P3
periods
SA–M
D * RM
P–M
S * M

other breeds was different ($P<0.05$); while Peppin Merino animals recorded the lightest negative conversion (o.1%) and their impact on the other breeds was significant ($P<0.05$). The Peppin breed had to maintain the least weight on the sparse pasture. The average negative conversion estimate of S.A. Merino and Suffolk cross sheep was about 3.0% and did not differ significantly ($P>0.05$).

4.4.2.2 Efficiency of Feed Conversion into Lean Tissues

Efficiency of feed conversion into lean tissue in the first period was at its highest (21%) for the Suffolk cross breds or 26%, 53% and 88% better at feed conversion than Dorset cross breds, S.A. Merino and Peppin Merino animals respectively ($P<0.05$). The breed effect was significant in this period ($P<0.05$).

In period 2 the two Merino strains averaged similar feed conversion coefficent, of 3.7% or 40% less than Suffolk cross ($P<0.05$). Dorset cross animals recorded a negative feed conversion coefficient and differed markedly from the other breeds ($P<0.05$).

In the final period the two cross bred groups were converting feed into lean tissues at a mean rate of 1.3% and were different ($P<0.05$) from the Merino strains which were 68% better feed converters.

4.4.2.3 Gross Efficiency

In Table 6 gross efficiency (ME gain/ME intake x 100) is shown and summarised in Figure 9c.

In period 1 the mean gross efficiency for the two Merino strains and the Suffolk cross breed was about 15% and did not differ ($P>0.05$), while Dorset cross lambs had a significantly higher gross efficiency of about 37% from the other breeds ($P<0.05$). In period 2 the Suffolk cross lambs had the highest gross efficiency of 21%, followed by Peppin Merino lambs with 10%, S.A. Merino lambs with 3.8%; however the Dorset cross breds recorded a negative gross efficiency coefficient due to the fact that they lost some body energy.

A significant difference was marked between the four breeds ($P<0.05$). In period 3 the four breeds were not converting ME intake efficiently. They recorded negative coefficients of about 11% for S.A. Merino and

Dorset cross bred lambs ($P>0.05$), 12.2% for Suffolk cross breds did differ from the remaining breeds ($P<0.05$), also Peppin Merino lambs had a negative feed conversion ratio of about 1.2% and differed markedly from the other breeds ($P<0.05$).

4.5 DISCUSSION

Growth may be viewed from at least two aspects; firstly, an increase in body mass (live weight) with time and, secondly, the changes in form or composition resulting from growth rates of the different body components.

This comparative study demonstrated some breed differences at one stage of growth and little at others.

Animal growth was different for each breed; some, such as the Suffolk Merino group grew more rapidly increasing their body mass by 10kg from August to January, while Dorset cross bred group managed an increase of 5.7kg until December, but in the space of a few weeks, due to low feed availability and the poor nutritive values of summer pasture, 48% of the accumulated gain was lost. Meanwhile the S.A. Merino

lambs gained almost 5kg in weight although they lost some of that in January. Peppin Merino animals grew at a much slower rate and showed a gain of nearly 4kg. They lost the least of the groups in January. Under comparable grazing conditions the Suffolk x Merino and Dorset x Romney Merino lambs were able to make greater body gains than the S.A. Merino and Peppin Merino lambs between the winter/spring and early summer periods; this is in accordance with Allden's findings (1970).

Body composition measurements revealed interesting points. Despite different body weights, lean body mass remained fairly constant for the two Merino strains and the Dorset cross breds. The Suffolk cross breds had a higher lean body mass due to the fact that they are large sized animals. However the amount of body fat content and energy did vary with body weight. Fat has a high energy value and therefore has a major impact on the energy content of the body. Thus fat and energy exhibited similar changes with live weight. The Suffolk Merino animals seemed to be the leanest throughout the experiment; they grew faster and did not accumulate significantly more fat. But Dorset cross and S.A. Merino animals appeared to have similar fat accretion trends and were much fatter

than Suffolk cross breds. The similarity between the S.A. Merino and Dorset cross breds is in agreement with the findings of Kellaway (1973) if compared at the same stage of maturity.

The results seem to be supporting Searle's and Graham's view (1972) that small mature size animals (such as S.A. Merino) tend to be fatter, weight for weight, than an animal of large mature size. Also Allden (1970) found no difference in fatness between S.A. Merino and Dorset horn x Merino wethers which are thought to be of similar mature size. However Peppin Merino breed did grow very slowly and appeared to be leaner than Searle's and Griffith's (1976). Peppin Merino flock, where they reported that their Peppin Merino wethers entered the fattening phase at a live weight of 26kg with a mean body fat of 5.2kg; Peppin merino used in this experiment recorded a mean body fat of 4.8kg at a 29kg live weight. This discrepancy might be attributed to different nutritional and environmental conditions. The Peppin Merino breed used in this experiment was kept grazing (outdoor conditions) while Searle's and coworker's group was kept penned and hand fed (indooor conditions).

Body composition of the experimental breeds appeared to be slightly different from the published data

(Searle 1977); but it did agree with the established principle such as animals of large mature size grow faster and enter the fattenting at relatively high body weight (i.e. Suffolk cross breds entered the fattenting phase at around 36kg, Dorset x Romney Merino at 33kg and S.A. Merino at 30kg live weight).

Feed intake, expressed as voluntary feed consumption (DMg/day) or metabolizable energy (ME) intake (MJ/day) was reported to be similar to all breeds; except in the December/January phase when the Suffolk cross wethers ate more than the S.A. and Peppin Merino groups (which might be attributed to higher nutrient requirements).

However one of the objectives of this experiment was to assess which breed used its feed more efficiently. Feed conversion is closely related to growth rate (or gain) expressed in terms of liveweight gain, or into lean tissue or in ME gain. Feed conversion efficiency is at its highest earlier in an animal's life and gradually declines as rate of maturity increases. This statement was verified by the four breeds used here. The Suffolk Merino breed was the best feed converter (due to high liveweight gain and lean body mass gain). The composition of feed intake (pasture)

dictated the animal's use of nutrients and its level of efficiency; and also need to be mentioned is the fact that the animal nutrient requirements and utilisation were affected by forage availability and quality (this explains the negative feed conversion efficiences witnessed in the last month of the experiment)[1]

Nonetheless efficiency can be influenced by age and the age at which an animal reaches maturity. As Blaxter (1964) suggested efficiency of growth declines with age : so, as the experimental breeds grew older their efficiences would have declined to some degree. in terms of degree of maturity, Suffolk x Merino animals demonstrated that they were the least mature group and in the specific context of producing lean meat animals, the Suffolk x Merino breed might be favoured. However even this group were relatively fat compared with say, goats and fatter than many breeds of cattle. In conclusion, it can be said that selection for leaner meat appears to be equivalent to selecting far better feed conversion and a less mature animal.

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(1) The calculation of gross efficiency in this experiment relied on measurement of feed intake that did not correspond in time with weight measurements - viz. the last feed intake measurements were made in November/December whereas the animals were weighted last in January when feed was sparse.

EXPERIMENT 2 : EFFECT OF ANDROGENIC AND ANDROGENIC PLUS OESTROGENIC AGENTS ON THE GROWTH AND BODY COMPOSITION OF SHEEP GRAZING OR PEN FED ROUGHAGE OR OIL SEED DIETS

5.1 INTRODUCTION

Apart from specific metabolic effects, a number of hormones influence the growth of many tissues of well-fed ruminant animals. As a result, growth can be controlled and manipulated by exogenous means using drugs known as anabolic agents. These growth "promotants" have been widely used to improve the productivity of meat animals, by increasing the efficiency of production and by lessening fat in the carcass. Ideally anabolic agents should improve growth rate, feed conversion efficiency and carcass qualities. Trenbolone acetate, which is a synthetic androgen, when administrated to cows, has been found to stimulate growth and improve carcass conformation by reducing fat deposition (Galbraith 1980(a)). When combined with oestradiol, it has been reported to increase significantly liveweight gain, food intake

and the carcass lean proportion in wether lambs (Sulieman et al 1986).

The purpose of the experiment reported here was to establish the effect of trenbolone acetate, and trenbolone acetate combined with oestradiol -17B on feed intake, feed conversion efficiency of wether lambs, either grazing or pen fed with roughage or an oil seed diet and to determine any changes that might have taken place in their body composition. The oil seed diet was used to alter the type of fatty acid in their intramuscular phospholipid prior to slaughter.

5.2 EXPERIMENTAL PROCEDURE

Eighteen Dorset ♂ X (Border Leicester X Merinos) ♀ wether lambs were randomly assigned to three treatment groups as follows : trenbolone acetate and oestradiol (Torelor^{R})* group; trenbolone acetate (Finaplix^{R})* group and control group.

Torelor group received 200mg of trenbolone acetate and 40mg of oestradiol.

---

* Finaplix^{R} (Hoechst International UK)

Torelor ^{R} (Roussel-Uclaf Paris)

Finaplix group received 300mg of trenbolone acetate.

The treated animals were implanted subcutaneously on the upper surface of the left ear flap with the appropriate anabolic compound.

The experiment was divided into three main phases:

- pasture phase;
- adlibitum pen fed phase
- restricted/oil seed pen fed phase.

5.2.1 Diets

(a) During the pasture phase the groups ran together on a grass dominated sward. The stocking rate was of 6 D.S.E. (Dry sheep Equivalent)/ha. The pasture yield (on offer at the beginning of the experiments) amounted to 1.8 tonne of dry matter per hectare.

(b) The adlibitum phase started two weeks after the adaptation period. The wethers were individually penned after the pastue phase and fed a prepared diet. Water was freely available. All groups were fed a lucerne/oat (1:1) premixed diet. Each sheep received a

daily weighed ration, and any residues were weighed. This phase lasted for four weeks.

(c) Restricted phase consisted of feeding a fixed ration of 800g of the premixed lucerne/oat diet (providing an estimated 8.36MJ of metabolizable energy). On the fifth week of the restricted phase, the first three wethers of each treatment were fed an oil seed diet composed of 250g of linseed plus 400g of lucerne (providing an estimated 8.58MJ of metabolizable energy); while the remaining sheep were kept on 800g lucerne/oat diet.

5.2.2 Measurements

At the beginning of each phase the animals were weighed. Tritiated water space was determined after azeotropic distillation of hydrogen isotopes (see Chapter 3). Body composition of the wethers was predicted by the multiple regression equations of Searle (1970). All body weights quoted in the results were fleece free weights, taken after 18-24 hours without food and water.

Feed intake in the pasture phase, was estimated from chromic oxyde slow release capsule technique (see

Chapter 3), three wethers from each treatment were randomly selected and fitted with chromic oxyde slow release capsules. Faeces were collected from harnessed animals. The chromic oxyde concentration was determined by atomic absorption spectrometer from faecal samples. The pasture dry matter digestibility was estimated *in vitro* (see Chapter 3). While in the *adlibitum* and restricted phases a daily recording of feed intake (offered ration - residue) was carefully taken.

5.3 RESULTS

5.3.1 Live Weight

Live weight data of the three groups are reported in Table 7. At the time of implantation day, the mean live weights were 28.5, 28.4 and 28.7kg respectively for Torelor, Finaplix and control groups. At the end of the pasture phase the two treament and control groups increased their live weights by 5.9, 5.2 and 5.0kg respectively for Torelor, Finaplix and control groups but were not statistically significant ($P>0.05$).

TABLE 7

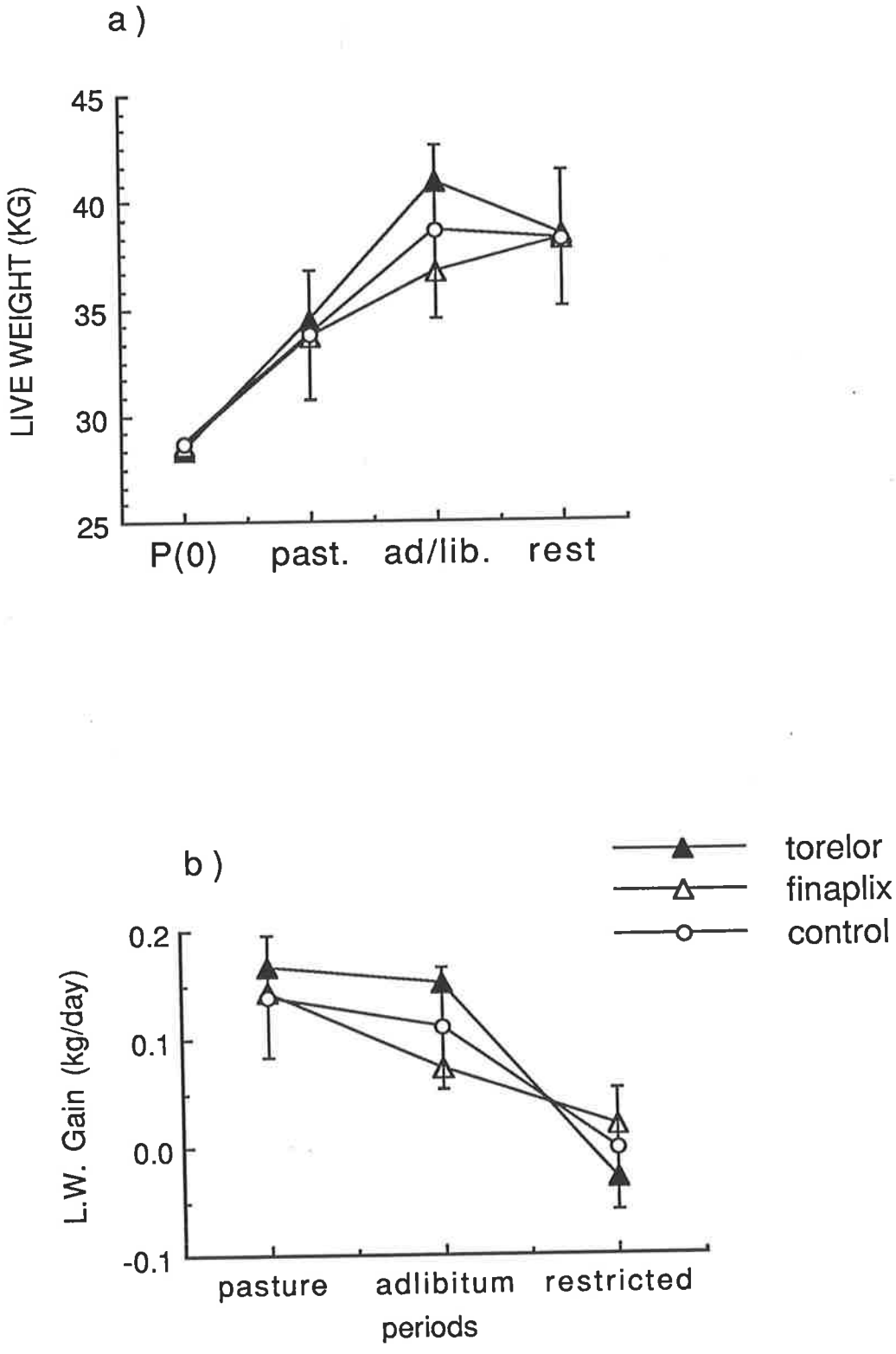
LIVEWEIGHTS AND LIVEWEIGHT GAINS OF TORELOR, FINAPLIX TREATED WETHERS AND CONTROL WETHERS

	PASTURE PHASE		ADLIBITUM PHASE		RESTRICTED PHASE	
	L.W.[a]	L.W.G.[b]	L.W.	L.W.G.	L.W.	L.W.G
TORELOR	34.43	0.165	40.9	0.150	38.40	(-0.03)
FINAPLIX	33.6	0.142	36.7	0.072	38.23	0.019
CONTROL	33.71	0.139	38.58	0.111	38.21	0.001
L.S.D. (P 0.05)	n.s.	n.s.	4.01 *	n.s.	n.s.	0.03 *

a : Liveweight (kg)
b : Liveweight gain (kg/day)

FIGURE 10

LIVE WEIGHT (kg), (a) AND LIVEWEIGHT GAINS (g/DAY); (b) OF TORELOR, FINAPLIX TREATED AND CONTROL WETHERS


a)
LIVE WEIGHT (KG)
45
40
35
30
25
P(0)
past.
ad/lib.
rest
b)
torelor
finaplix
control
L.W. Gain (kg/day)
0.2
0.1
0.0
-0.1
pasture
adlibitum
restricted
periods

While in the adlibitum pen fed phase Torelor animals exhibited the heaviest live weight, followed by control and Finaplix. Torelor and control were not significant but Torelor and Finaplix treatments were significantly different ($P<0.05$) and Finaplix and control groups were not. Torelor animals reached a live weight 10.3% higher than the Finaplix and 5.6% than control animals; control's live weight was 4.9% higher than Finaplix. In the restricted phase, Torelor wethers lost weight, control group maintained its live weight while Finaplix increased its live weight, but from a statistical point of view the three groups were not significantly different.

On the other hand the analysis of variance (ANOVA) carried out on liveweight gains for the three phases showed that the pasture phase and adlibitum phase were not significantly different, the three groups were gaining an average of 0.149kg/day, for the pasture phase and an average of 0.110kg/day for the adlibitum phase. However in the restricted phase, Finaplix treatment was gaining 19g/day while Torelor was losing in the order of 3g/day and control group was maintaining 1.8g/day of gain. There was no significant difference between Finaplix and control, but Finaplix and Torelor groups and also Torelor and control groups were significant ($P<0.05$).

Torelor treated wethers exhibited the highest live weight and liveweight gain figures when run under optimal conditions such as lightly stocked pasture phase and adlibitum phase but under the controlled restricted phase were unable to maintain the same trend. Finaplix treated wethers and the control ones showed similar growth patterns, the Finaplix group took longer to reach the 38kg liveweight mark.

5.3.2 Body Composition

As live weights increased the lean body mass did not increase markedly. Control animals maintained a fairly constant lean body mass throughout the experiment while Finaplix group showed a slight increase of lean body mass through the different phases. Torelor treatment increased the lean body mass by 2.0kg between the pasture and the adlibitum phases but a decline of 4.00kg was observed in the restricted phases. Differences between treatments and phases were small and not significant ($P>0.05$) (see Figure 11a,1).

Body fat content, all groups exhibited the same amount in the pasture phase. An increase in fat content was observed in the adlibitum phase with the highest

content found in the control and Torelor, Finaplix and Torelor were not different ($P>0.05$) while Finaplix and control were different ($P<0.05$). No difference was observed in the restricted phase for the three groups. Depsite the liveweight loss of Torelor in the restricted phase, the fat content was on the increase (see Figure 11b).

The overall result of body energy appears to be on the increase despite the dietary trends. Finaplix sheep presented the lowest energy content values throughout the experiment, while Torelor and control sheep tended to have similar values in each phase. In the adlibitum phase Finaplix and control group were different ($P<0.05$) (see Figure 11c).

5.3.3 Feed Intake and Efficiency of Feed Conversion

5.3.3.1 Feed Intake

The intake is expressed in:

a) DMFI = Dry matter feed intake (kg/day)

b) MEI = Metabolizable energy intake (MJ/day)

TABLE 8

BODY COMPOSITION OF TORELOR, FINAPLIX TREATED AND CONTROL WETHERS

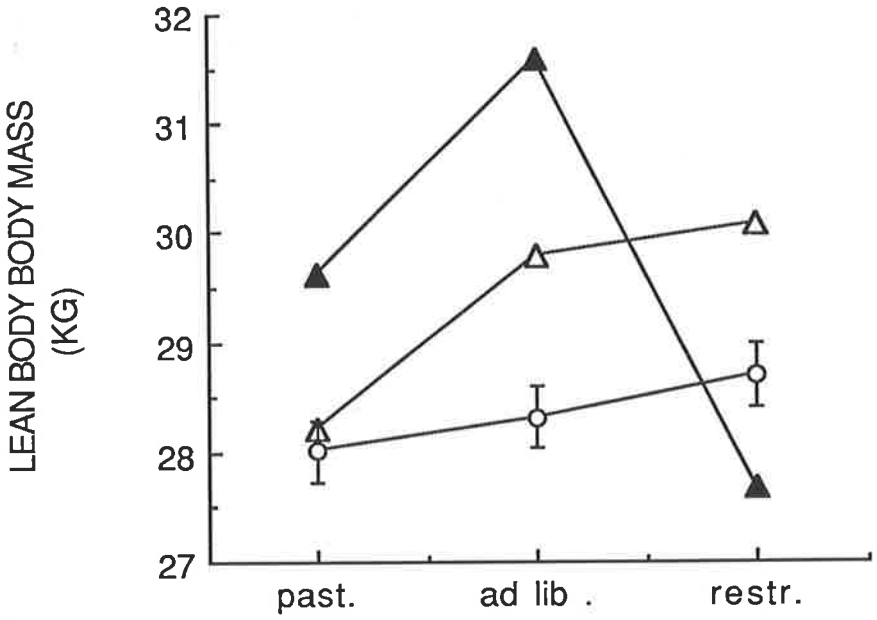
TREATMENT	PASTURE PHASE			ADLIBITUM PHASE			RESTRICTED PHASE		
	LEAN BODY MASS (1)	FAT (2)	ENERGY (3)	LEAN BODY MASS (1)	FAT (2)	ENERGY	LEAN BODY MASS	FAT	ENERGY
TORELOR n=6	29.61	5.15	371.12	31.60	8.80	523.34	27.70	10.75	576.40
FINAPLIX n=6	28.21	5.16	373.50	29.78	7.22	450.85	30.09	8.48	496.7
CONTROL n=6	28.01	5.61	373.68	28.32	10.25	560.64	28.70	9.65	535.12
L.S.D (P<0.05)	- n.s.	- n.s.	n.s.	- n.s.	2.22 *	82.43 *	- n.s.	- n.s.	- n.s.

(1) Lean Body Mass (kg)
(2) Total Body Fat (kg)
(3) Body Energy Content (MJ)

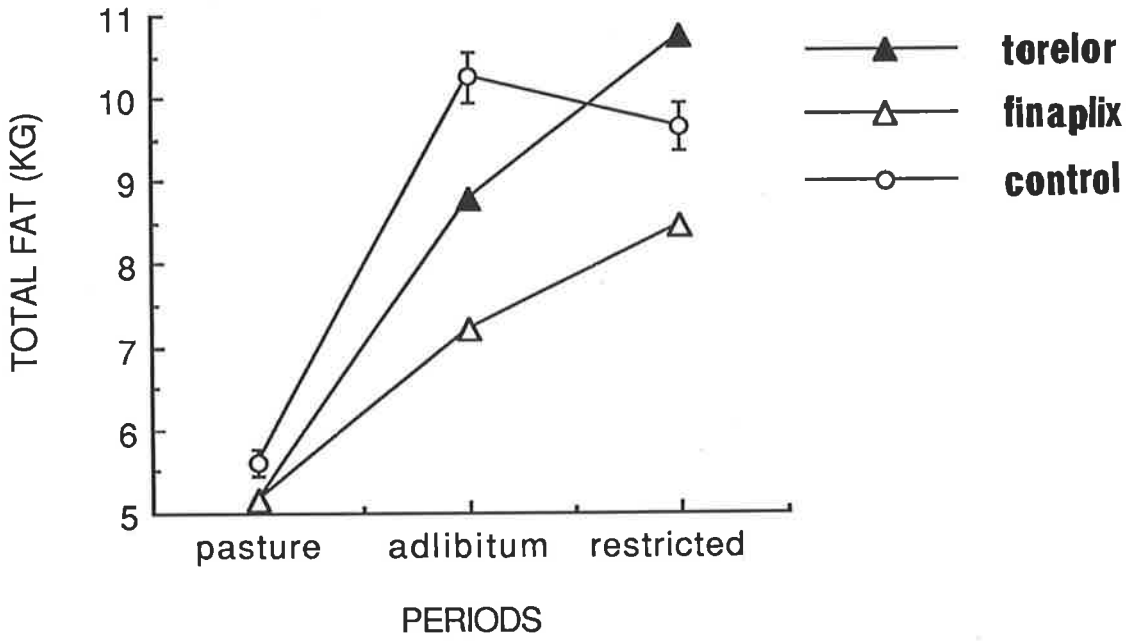
FIGURE 11

BODY COMPOSITION OF TORELOR AND FINAPLIX TREATED AND CONTROL WETHERS, a) LEAN BODY MASS (kg); b) FAT (kg), AND c) ENERGY (MJ)

a)


LEAN BODY BODY MASS
(KG)
32
31
30
29
28
27
past.
ad lib .
restr.

b)


TOTAL FAT (KG)
11
10
9
8
7
6
5
pasture
adlibitum
restricted
PERIODS
torelor
finaplix
control

c)

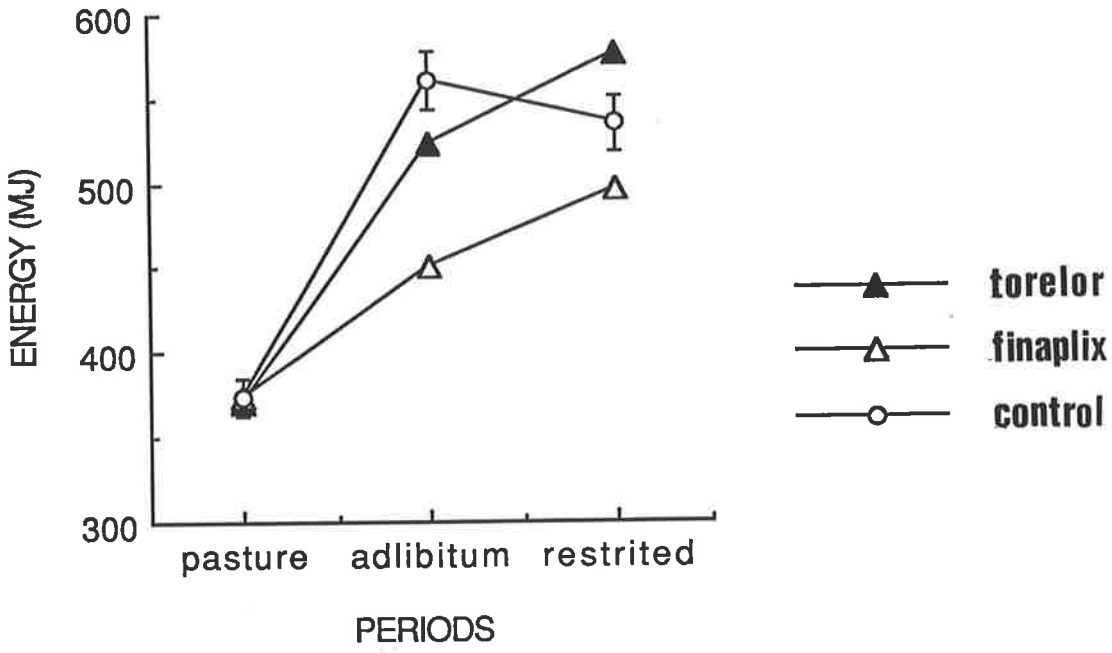

600
500
400
300
ENERGY (MJ)
pasture
adlibitum
restrited
PERIODS
torelor
finaplix
control

TABLE 9

FEED INTAKE AND EFFICIENCY OF FEED CONVERSION OF TORELOR, FINAPLIX AND CONTROL WETHERS

	PASTURE PHASE					ADLIBITUM PHASE					RESTRICTED PHASE				
	a	b	c	d	e	a	b	c	d	e	a	b	c	d	e
TORELOR n=6	1.386	15.65	11	10.8	9.4	1.360	14.198	10.6	3	28	$\frac{0.800}{0.650}$	$\frac{8.36}{8.58}$	(-3.7)	(-3.7)	12.2
FINAPLIX n=6	0.844	9.285	16.2	16.2	13.6	1.492	15.60	4.7	2	12	$\frac{0.800}{0.650}$	$\frac{8.36}{8.58}$	(-1.3)	7.5	9.7
CONTROL n=6	1.205	13.23	12	6.9	17.9	1.268	13.243	6.5	(-1.7)	24	$\frac{0.800}{0.650}$	$\frac{8.36}{8.58}$	0.4	1.8	(-1.8)
L.S.D. (P<0.05)	0.186*	2.08*	n.s.	n.s.	n.s.	n.s.	n.s.	5.2*	n.s.	n.s.	n.s.	n.s.	3.9*	n.s.	n.s.
(P<0.01)	0.267**	3.00**													

a = Dry Matter Intake (kg/day)
b = Metabolizable Energy Intake (MJ/day)
c = Efficiency of Feed Conversion (Liveweight gain/intake) (%)
d = Efficiency of Feed Conversion (Lean body mass gain/intake) (%)
e = Gross Efficiency (Energy gain/MEI) (%)

In the pasture phase, Finaplix sheep had the lowest DMFI and MEI while Torelor group recorded the highest feed intake. The DMFI and MEI of Torelor and control were different ($P<0.05$). DMFI of Torelor and control were different ($P<0.05$) while their MEI were not ($P>0.05$). However control's DMFI and MEI were highly different from Finaplix' ($P<0.001$). (A logarithmic transformation was applied but did not alter the significance levels. As a result the untransformed data are given for ease of interpretation and to avoid problems of bias in back transforming from the means of the logarithmic data to the original units). However in the adlibitum phase no difference was observed between groups for DMFI and also for MEI ($P>0.05$) (see Figure 12a, b).

5.3.3.2 Efficiency of Feed Conversion and Gross Efficiency

Efficiency of feed conversion is expressed in terms of:

a) liveweight gain/DMFI

b) lean body mass gain/DMFI

while gross efficiency is expressed as ME gain/MEI. Table 9 shows that efficiency of feed conversion from

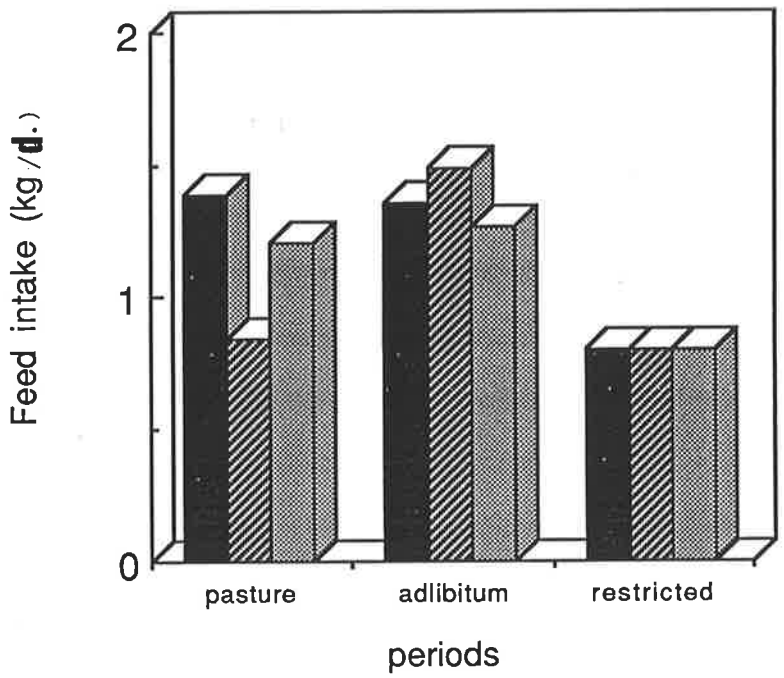
liveweight gain, in the pasture phase, Torelor and control animals recorded similar coefficients of 11 and 12% while Finaplix treated sheep were better feed converter (16%); but the differences were not significant ($P>0.05$). This might be attributed to the fact that their intake was the lowest; while in the adlibitum phase, Torelor sheep were the most efficient in feed conversion followed by control and Finaplix groups. Torelor and control groups, and control and Finaplix groups were not different ($P>0.05$) while the mean difference between Torelor and Finaplix was 6% and Fisher protected L.S.D. ($P<0.05$) was 5.2%; a slight difference was recorded due to the fact that the F test was not significant.

In the restricted phase no difference was noticed between linseed/lucerne and lucerne/oat fed animals within nor between groups. Food conversion efficiency declined markedly for the 3 groups, Finaplix animals managed to convert their intake into body tissues at the rate of 1.3% and the control group at 0.4% but their difference was not significant ($P>0.05$). On the other hand Torelor treated animals were not converting feed efficiently into body tissues, due to the fact that they were losing weight. The negative feed conversion was of the order 0.32%. Torelor v. Finaplix and Torelor v control were different ($P<0.05$) (see Figure 13a).

FIGURE 12

FEED INTAKE OF TORELOR, FINAPLIX TREATED AND CONTROL WETHERS, a) FEED INTAKE (kg/DAY), AND b) METABOLIZABLE ENERGY INTAKE (MJ/DAY)

a)


Feed intake (kg/d.)
2
1
0
pasture
adlibitum
restricted
periods

b)

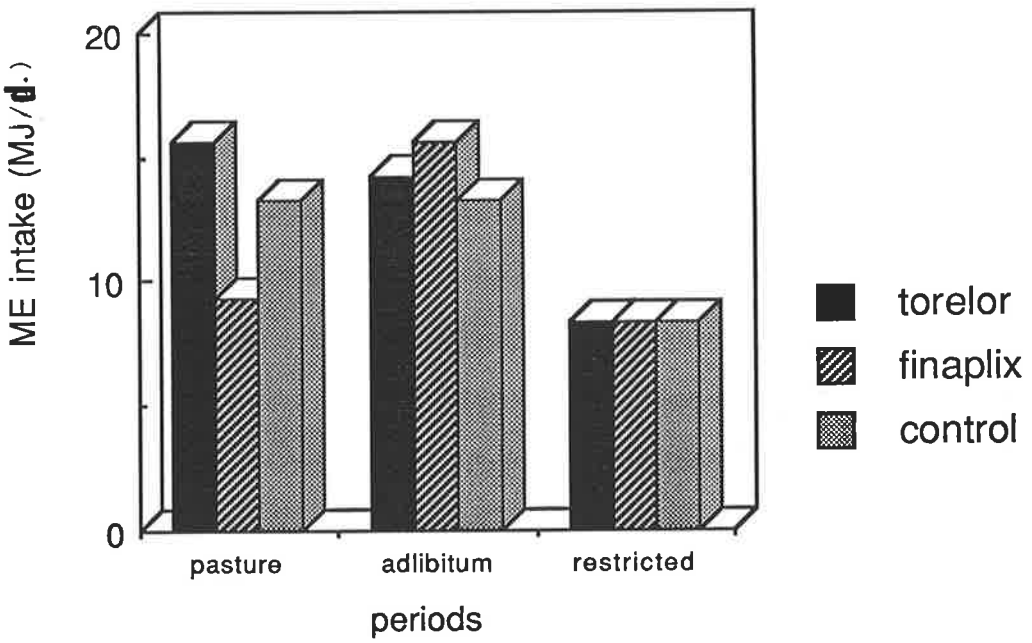
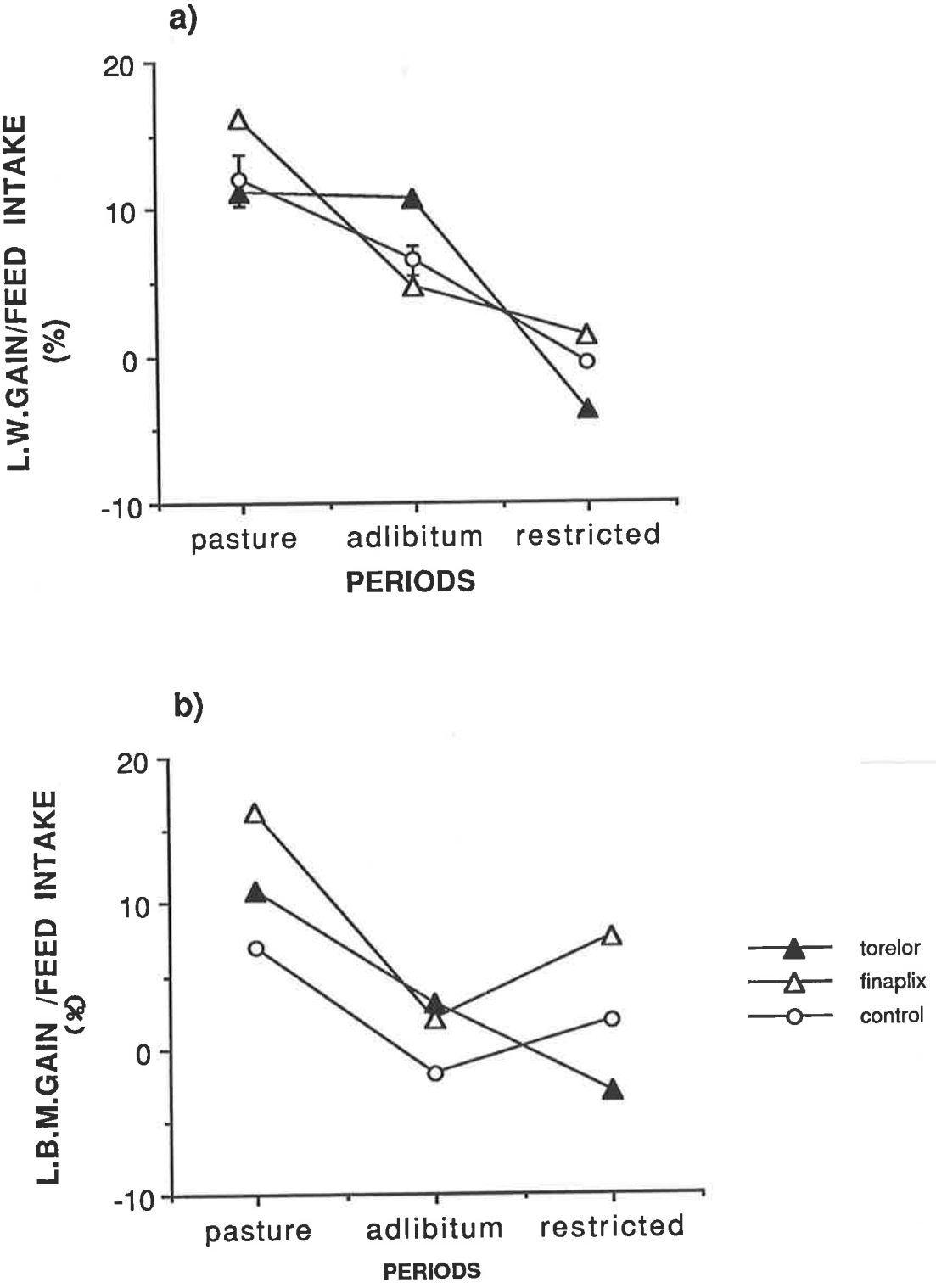
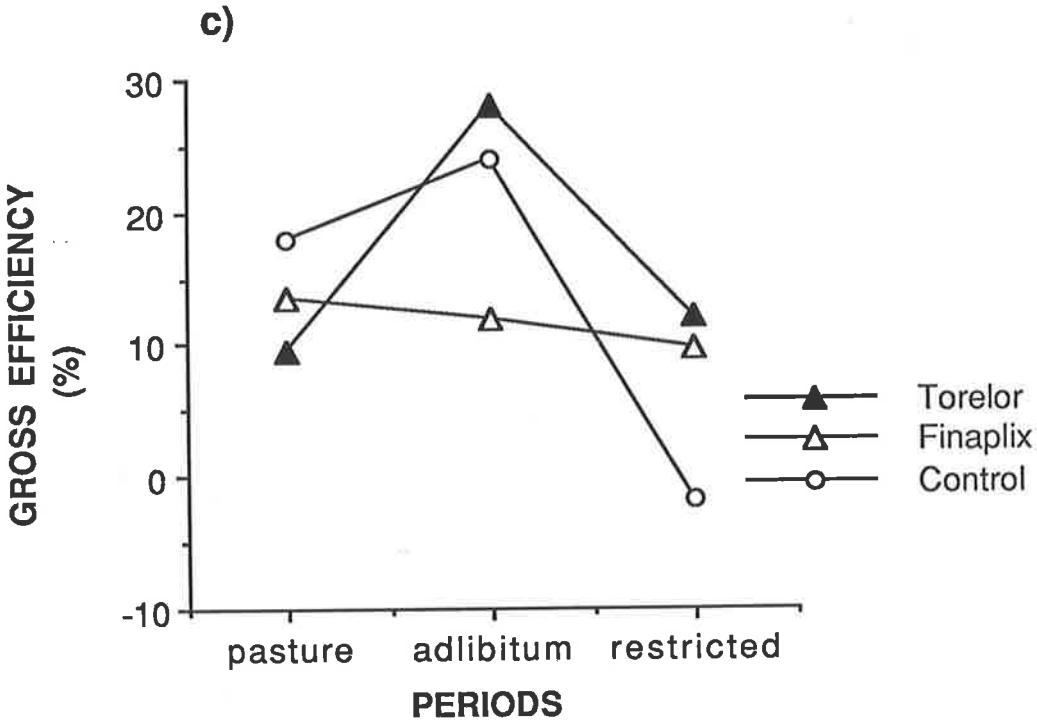

ME intake (MJ/d.)
20
10
0
pasture
adlibitum
restricted
periods
torelor
finaplix
control

FIGURE 13

EFFICIENCY OF FEED CONVERSION OF TORELOR, FINAPLIX TREATED AND CONTROL WETHERS, EXPRESSED IN TERMS OF, a) LIVEWEIGHT GAIN/FEED INTAKE; b) LEAN BODY MASS GAIN/FEED INTAKE, AND c) GROSS EFFICIENCY ME GAIN/ME INTAKE


a)
20
10
0
-10
L.W.GAIN/FEED INTAKE
(%)
pasture
adlibitum
restricted
PERIODS
b)
20
10
0
-10
L.B.M.GAIN /FEED INTAKE
(%)
pasture
adlibitum
restricted
PERIODS
torelor
finaplix
control


c)
GROSS EFFICIENCY (%)
30
20
10
0
-10
pasture
adlibitum
restricted
PERIODS
Torelor
Finaplix
Control

Efficiency of feed conversion into lean tissues is shown in Table 9. No significant difference ($P>0.05$) was reported throughout the experiment. Although Finaplix treated sheep have shown to be the most efficient converters of lean tissues in the pasture phase and restricted phase (16.2 and 7.5% respectively); while during the adlibitum phase the efficiency coefficient dropped to a low 2%. Torelor implanted wethers control group followed similar patterns with being good feed converters. At the pasture phase (10.8 and 6.9% respectively) they became poor converters from the adlibitum to the restricted phases (with 3.0 and -3.7%) for Torelor and (-1.7) to 0.4% for control (see Figure 13b).

The trends in gross efficiency (body gain/total intake) are reported in Table 9 and shown in Figure 13c. Throughout the experiment no statistical difference had been encountered. At the pasture phase control animals demonstrated a gross efficieny of 17.9% followed by Finaplix 13.6% and Torelor 9.4%. In the adlibitum phase Torelor treated animals registered the highest gross efficiency 27.9% followed by control 24.2% and Finaplix 12.0%. While in the restricted phase the gross efficiency of the three groups dropped to 12.2, 9.7 and -1.8% for Torelor, Finaplix and control animals.

5.4 DISCUSSION

Both trenbolone acetate and oestradiol increase the growth of ruminants under adequate feed conditions (Van der Wal 1976). Trenbolone acetate is a synthetic androgenic agent which not only promotes growth but lessens fat deposition in ewes (Sulieman *et al* 1981).

There is a causal relationship between live weight and body composition. As the bodyweight of an animal increases its chemical components increase accordingly and their proportions one to another change.

Torelor (trenbolone acetate and oestradiol) treated wethers in this experiment did tend to grow more quickly than Finaplix (trenbolone acetate alone) and control animals when run under optimal conditions of the lightly stocked pasture phase and the adlibitium pen fed phase. Torelor animals increased their initial live weights at the *adlibitum* phase by 43.5%, or 8.6% higher than the control animals while Finaplix (trenbolone acetate) treated sheep managed to increase their initial live weights by 29.0% or 5.8% lower than the control group and 14.5% lower than the Torelor animals. Anabolic agents had affected the growth of the treated animals, high growth rates occurred with

combined hormones (trenbolone acetate and oestradiol); this observation is in accordance with the finding of Coelho and co-workers (1981). While the androgenic compound (trenbolone) administered alone to wethers showed slower growth rates, this was probably due to the fact that castrated males are less responsive to androgens given alone (Stollard et al 1977).

However during the restricted phase no significant effect was observed between animals fed lucerne/oat and linseed/lucerne diets. Torelor wethers however lost weight at the rate of 3g/day or 6.51% of their adlibitum weight while Finaplix sheep increased their live weights from the previous phase by 4.0% and the control group increased its live weight by 0.9%.

Body composition results showed that fat increased linearly throughout the entire experiment for each of the 3 groups. At the pasture phase, the three groups recorded the same amount of fat (about 15.5%). At the adlibitum phase the control animals recorded the highest increase of fat content of 26.6% or about 10% more than the previous phase, while Torelor and Finaplix treated lambs had an average increase of 5.5%. However during the restricted phase control animals lost 1.3% of their fat content while Finaplix sheep increased by 2.5% their body fat, despite a

liveweight loss. Torelor animals managed to keep a constant fat increase of 6.5%. As mentioned earlier, Finaplix treated animals showed a delayed, or a much slower growth compared with the control animals, however Torelor treated wethers demonstrated a lower fat accretion on one hand, yet on the other, achieved the highest live weight (40.9kg). This might be attributed to the effects of the combined anabolic agents on diversion of energy from fat to (say) protein growth, as reported by Byers (1982). Concerning the increase of body fat of Torelor group during the restricted phase, this might be due to the fact that nutritional restriciton on sheep over 36kg live weight has at first no effect on fat but subsequently reduced as Greenhalgh reported it in his review (Greenhalgh, 1986).

Lean body mass of the three groups throughout the experiment did not differ statistically. However Torelor animals were 20% leaner than Finaplix and control animals. Also in the adlibitum phase Torelor lean body mass was 3.6% higher than control and 6.0% higher than Finaplix group. But in the restricted phase Finaplix lean body mass was 8 and 4.6% higher than Torelor and control animals respectively. Lean body mass data did not show any statistical differences between treated and control animals,

probably because of the small numbers of animals used. Combined trenbolone acetate plus oestradiol implants appeared to have a more immediate effect on growth than trenbolone acetate alone, but at the restricted phase the trenbolone acetate implant alone appeared to be more effective. This observation pointed out that trenbolone acetate might be effective at increasing growth rate of wethers several weeks after implantation while oestradiol benefits are transient on growth as reported by Sillence co-workers (1987).

The effect of anabolic agents on feed intake and efficiency of feed conversion, was parallel with the effect on growth rate. Torelor animals recorded 15% and 7% more feed intake than the controls in the pasture and adlibitum phases, while Finaplix treated wethers had 30% lower and 18% higher feed intake than the controls in the first two phases. Torelor animals consumed approximately 38% more feed than Finaplix animals during the pasture phase while in the adlibitum phase Finaplix treated wethers' feed intake was exceeding Torelor's by 9.7%. In the pasture phase Finaplix animals converted more efficiently food into liveweight gain and lean tissue gain than Torelor and control groups. However in the adlibitum phase Torelor animals were significantly more efficient in converting feed to liveweight gain than Finaplix and

control animals while in the restricted phase feed conversion efficiencies in terms of liveweight gain and lean tissue were very low for Finaplix and control animals, and even negative for Torelor animals. Regarding gross efficiency results, variations have been observed throughout the 3 phases. Gross efficiency seemend to be related to fat accretion (fat contains 34.3MJ/kg by contrast to the energy retained in 1kg of fat-free muscle tissue is about 5MJ (Webster 1977).

As the fat content of an animal increases so does the energy content. The highest gross efficiencies were reported in the adlibitum phase for Torelor and control animals with 28 and 24% respectively. Although, in the restricted phase, liveweight gains of Torelor were negative, their fat content increased and their gross efficiency value was in the order of 12% despite a negative conversion efficiency.

Liveweight gains and feed conversion efficiency were closely related. Feed conversion efficiencies were slightly improved with both anabolic agents. The impact of anabolic agents on feed intake was not that marked, except for the action of Finaplix (trenbolone acetate) during the pasture phase; the overall

treatment differences were small and generally not significant. Plane of nutrition seemed to have little effect on body composition of treated and control animals as reported by Therriez and co-workers in 1982.

In summary it can be stated that when feed was freely available, oestradiol with trenbolone acetate increased the feed consumption and energy intake of growing lambs. Trenbolone acetate alone appeared to increase feed intake after a period of time, but had no action over the first few weeks of treatment. In other words, there was a slow response. The net effect of the two hormone treatments after periods of pasture and adlibitum pen feeding was for oestradiol to increase the mean live weight of animals to the largest value of the three groups, and for trenbolone acetate alone to produce the leanest animals not significantly different to the control animals in live weight. Because the oestradiol treated animals consumed more feed soon after treatment and commenced gaining weight earlier, they produced a greater quantity of lean tissue after 8 weeks, although over the second 4 weeks both groups and the trenbolone increased their lean body mass at the same rate. The combining of the two hormones was thus effective.

Possibly, without the presence of trenbolone in the Torelor implant, this group may have laid even more fat than they did. In terms of lean tissue production (retail product), the animals treated with trenbolone were the most efficient. At the end of the restricted phase of feeding these animals recorded the highest live weight, although not the highest energy due to their low fat content.

EXPERIMENT 3 : THE EFFECTS OF THE FATS OF RED MEAT ON PLASMA CHOLESTEROL

6.1 INTRODUCTION

Epidemiological studies have established a positive correlation between overnutrition (excess intake of energy, fats, salt, sugar and alcohol) and many common diseases of western man (occlusive vascular diseases, obesity, hypertension and certain cancers). The consumption of fat, particularly saturated fat, has been strongly correlated with incidence of coronary heart disease (CHD) across a range of countries (Keys 1970). This correlation is associated with another between CHD and the plasma cholesterol of populations; the incidence of CHD being greatest in western countries and least in the developing countries or in those populations that do not consume large quantities of saturated fat (eg Italy). This correlation has led to the association of red meat with CHD, as red meat can have a large proportion of saturated fat in comparison to fish and white meat. Also when raised

under certain conditions, red meat presents a high fat content.

It has been noted by Crawford (1975) and by Sinclair, O'Dea and Slattery (1982) that meat from many wild species of grazing animals (some of which are ruminants) has a lower fat content and a different fatty acid composition. Natural selection has led toward lean animals whereas selection by man has led to early maturing, fatter animals (Webster 1977, Siebert and Howard 1984). In association with the leanness of wild herbivorous species (deer, horse, kangaroo) has been an increase in the W-3 type of fatty acids and also an increase in the ratio polyunsaturated/saturated fatty acids (Sinclair et al 1982). The W-3 fatty acids are often associated with oils of marine origin and are found to be rich in cold water fish. Populations who consume large quantities of W-3 fatty acids have a low incidence of CHD (Sinclair 1985).

Thus there are several dietary means that might be used to achieve a reduction in CHD in western society. The first would be to cease consuming saturated fats from animal origin completely (ie to turn to vegetarianism). Secondly is for the public to consume small quantities of saturated fats from dairy

products and to eat meat low in fat content (ie meat from lean animals or cuts of meat trimmed of fat). A third possibility is to eat meats that have a higher proportion of the W-3 fatty acids (either from fish, red meat from wild species or meat from domestic animals that has been modified).

The two experiments that follow describe the effects on the plasma cholesterol of meat eating animals of:

(i) meat that difffered markedly in fat content; and

(ii) meat of moderate fat content that was modified by feeding different types of fatty acids to the meat animal prior to slaughter.

In each case the meat was processed and incorporated into the diet of pigs which acted as experimental models for human purposes.

6.2 EXPERIMENT 3a : EFFECTS OF MEAT OF DIFFERENT FAT CONTENT ON THE PLASMA LIPIDS

6.2.1 Experimental Procedure

6.2.1.1 Diets

The meat from animals raised in the first experiment was removed after slaughter and minced. Samples of the longissimus dorsi muscle were taken at slaughter and were analysed for a number of lipid components using the chloroform-methanol (2:1 w/w) procedure (see Chapter 3) and the results are shown in Table 11.

The meat from the Dorset cross bred group and South Australian Merino group of sheep was used to produce meat-based diets of which and with a cereal diet were fed to pigs in a latin square designed experiment. The composition of the 3 diets is reported in Table 9. The low fat meat diet was derived from South Australian Merino group was relatively low in total fat (4.5g/100g; 13KJ/100KJ) while the high fat meat diet (18.5g/100g; 45KJ/100KJ) was derived from the carcass of Dorset X Romney Merino groups. In order to match the level of fat in the high fat diet with that consumed by human populations such as average Australians (viz. 40% in energy terms) beef fat was added to the ration. The cereal diet (commercial pig feedstuff) comprised approximately 75% of cereals, 18% of legume and oil seeds and 3% of meat meal.

6.2.1.2 Animals

The animals used were 6 pigs of Kangaroo Island strain. Their average live weight was 47kg at the start of the experiment. They were fed isocalorically, providing an energy intake of 215KJ/kg L.W./day, regardless of the diet. Each of the 3 formulated diets was given to each pair of pigs for a period of three weeks.

6.2.1.3 Measurements

At the end of each feeding period the pigs were fasted for 16 hours and 20ml of blood was taken from the jugular vein and collected into ice-cold tubes containing heparin as an anti-coagulant. Plasma was removed after centrifugation and stored at -20°C until analysed for cholesterol and high density lipoprotein (HDL) fraction. Plasma was analysed for cholesterol content by gas-chromatography (GLC) using an internal standard method. From a stock solution containing 1mg/ml of Stigmasterol, 100 ul was placed in a small tube and evaporated to dryness with gaseous nitrogen. To this was then added 100 ul of plasma and 2ml of 95% ethanol and 100 ul of 33% potassium hydroxide. The mixture was incubated for 30 minutes

at 60°C in a water bath, then 2ml of hexane and 1ml of water was added and capped tubes shaken vigorously for 1 minute. The top hexane layer which separated (sometimes needing centrifuging) was removed into reaction vials and evaporated with gaseous nitrogen. To the dried tube was added 100 ul of chloroform and after purification through biosil, injected into the gas chromatograph (Varian 1400) for analysis against the internal standard. The column used was a 10m BP-1 (SGE Melbourne) 0.53mm in diameter and was run with a hydrogen carrier gas at 240°C.

The results were subjected to an analysis of variance appropriate to initial experimental design.

6.2.2 Results

6.2.2.1 Carcass and Fat Depth

At slaughter, the Dorset cross bred group and the S.A. Merino group had mean carcass weights of 18.4 and 13.0kg respectively and differed significantly ($P<0.05$). Fat depth measurements (taken at the 12th rib) showed that the Dorset cross bred group had 2.9 times more subcutaneous fat than S.A. Merino group ($P<0.05$) (Figure 14).

TABLE 10

THE COMPOSITION OF LOW AND HIGH FAT MEAT-BASED DIETS AND A LOW FAT CEREAL DIET FED TO PIGS (g/50kg LIVEWEIGHT/DAY)

COMPONENT	LOW FAT (Animal)	HIGH FAT (Animal)	LOW FAT (Cereal)
Meat (lean or fat)	275	275	-
Cereal (barley)	425	150	-
Sugar	145	195	-
Oil (safflower)	15	15	-
Fat (beef)	-	60	-
Feed Pellets	-	-	925
Total	860	695	925
Energy (kJ/day)	10750	10750	10750
Protein (g/day)	134	103	152
Fat (g/100g)	4.5	18.5	4.0
(kJ/100kJ)	13.3	45.5	8.0
Cholesterol (mg/day)	137	167	14
Polyunsaturated / Saturated	1.6	0.3	1.0

TABLE 11

CARCASS WEIGHTS AND FAT DEPTHS OF DORSET X ROMNEY MERINO AND SOUTH AUSTRALIAN MERINO BREEDS

BREED	CARCASS WEIGHT (kg)	FAT DEPTH (mm)
Dorset X Romney Merino	18.38	14.0
South Australian Merino	13.02	4.3
L.S.D. (P<0.05)	1.72 *	3.15 **

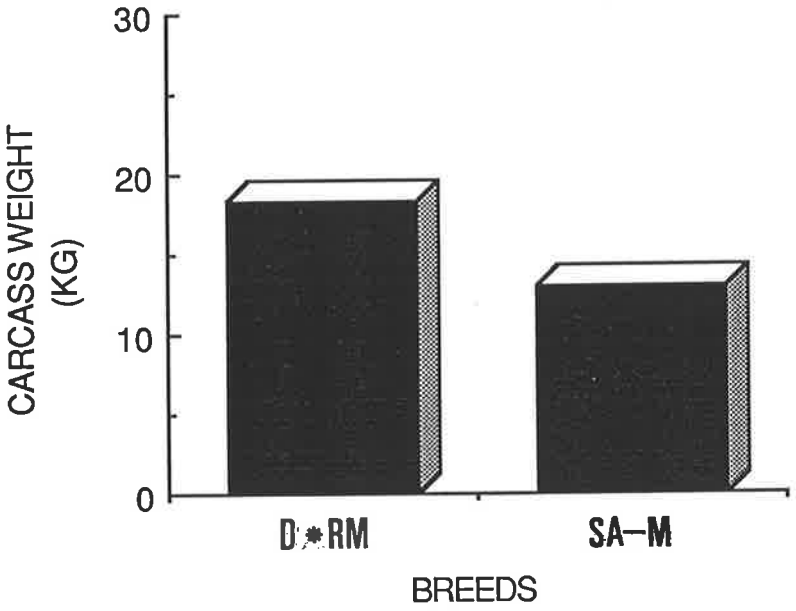
6.2.2.2 Fatty Acid Composition of Intramuscular Lipid

Muscle samples taken from the Dorset corss breds and the S.A. Merino animals were analysed individually for firstly total lipid content, and secondly for fatty acid profiles of the total lipid and the phospholipid. Table 11 summarises the results obtained. The Dorset cross breds contained much more intramuscular fat (almost twice as much) than S.A. Merinos. From subsequent analysis, the phospholipid and cholesterol contents amounted to mean values of 1%

FIGURE 14

CARCASS WEIGHT AND FAT DEPTHS OF DORSET CROSS BREDS AND SOUTH AUSTRALIAN MERINO LABMS AT SLAUGHTER, a) CARCASS WEIGHT (kg), AND b) FAT DEPTH (mm)

a)


30
20
10
0
CARCASS WEIGHT (KG)
D*RM
SA-M
BREEDS

b)

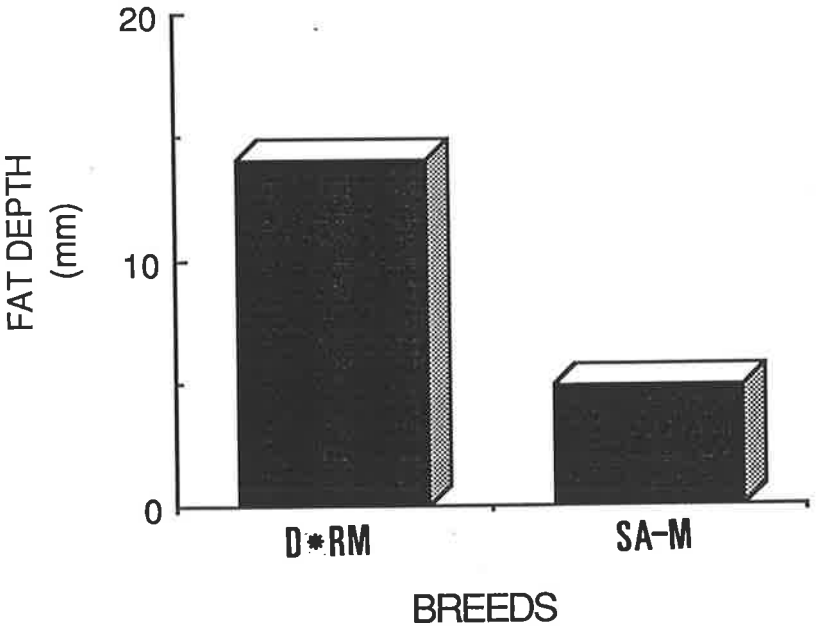

20
10
0
FAT DEPTH (mm)
D*RM
SA-M
BREEDS

TABLE 12

BODY COMPOSITION DATA AND INTRA-MUSCULAR LIPID OF DORSET CROSS BRED AND SOUTH AUSTRALIAN MERINO BREEDS PRIOR TO SLAUGHTER

ANIMAL TYPE		DORSET x ROMNEY MERINO		SOUTH AUSTRALIAN MERINO	
Body weight (kg)		34.6		31.9	
Total body fat (% body weight)		22.5[a]		10.8[a]	
Intramuscular fat (% wet tissue)		5.9[a]		3.3[a]	
Phospholipid (% wet tissue)		0.9		1.1	
Cholesterol (mg/100g tissue)		53.0		49.5	
Fatty acids (% total present) (C - chain length)		P/L	T/L	P/L	T/L
S	16:0	11.9	21.3	10.5	19.1
S	18:0	11.7	18.2	12.2	21.0
P	18:2 (W-6)	9.6[a]	3.1	12.4[a]	4.8
P	18:3 (W-3)	4.0	1.6	3.9	1.8
P	20:4 (W-6)	5.7[a]	0.8	7.6[a]	2.2
P	22:5 (W-3)	3.8	0.7	3.7	1.3
	P/S	0.86	0.15[a]	0.96	0.25[a]
	W-6/W-3	1.22[a]	1.90[a]		

a Significantly different within same line $P < 0.05$

Where: S = Saturated fatty acids
P = Polyunsaturated fatty acids
P/L = Phospholipids
T/L = Total lipid

and 51.2 mg/100g tissue respectively for both breeds. However the triglyceride contents (not shown) were significantly higher in the fatter group ($P<0.05$). In the phospholipid fraction the saturated fatty acid proportions did remain similar in both breeds, but greater concentrations of W-6 type (C 18:2 and 20:4) were observed in the South Australian Merino breed than in the Dorset cross breds ($P<0.05$) concentration of W-3 type in both breeds was similar ($P>0.05$).

The P/S ratios of total lipids was found to be 66% greater in S.A. Merino samples than in the Dorset cross animals. The W-6/W-3 ratio was significantly higher in S.A. Merino than Dorset cross animals ($P<0.05$).

6.2.2.3 Total Cholesterol and High Density Lipoprotein (HDL) Cholesterol of Pigs Fed Meat Diets of Different Fat Content

Cholesterol values of pigs fed a low fat meat diet were 11% lower than that of the low fat cereal diet and 38% lower than that of the high fat meat diet. The difference was highly significant with the meat diets ($P<0.01$). Low fat (cereal) diet animals presented a mean cholesterol value 34% lower than high fat fed pigs ($P<0.01$).

TABLE 13

MEANS OF CHOLESTEROL AND HIGH DENSITY LIPOPROTEIN CHOLESTEROL IN PLASMA OF PIGS FED DIETS BASED ON LEAN OR FAT OR CEREAL DIETS

DIET	CHOLESTEROL (mmol/L)	HDL CHOLESTEROL (mmol/L)
Low fat (meat)	1.397	0.793
High fat (meat)	2.278	1.387
Low fat (cereal)	1.550	0.778
S.E.D.	0.099	0.093
P<0.01	* * *	* * *

HDL cholesterol of both low fat fed groups were similar. High fat diet fed pigs showed a high density lipoprotein value that was approximately 44% higher than the low fat diets ($P<0.01$).

6.2.3 Discussion

Dorset cross lambs scored a much higher back fat, and had a heavier carcass weight than South Australian Merino lambs. Dorset cross animals are faster growing animals than Merinos and might have slightly more bone (Seebeck 1966). While S.A. Merino lambs yielded a lower carcass from similar body weight, this is also in accordance with Seebeck's (1966) findings. However, if both breeds were compared to the same stage of maturity, as reported by Kellaway (1973) they probably would have yielded similar carcass weight and had similar back fat scores.

The results of the intramuscular fatty acid analysis showed that the additional triglyceride laid down in Dorset cross lambs lowered the P/S ratio. The W-6/W-3 ratio did vary considerably between breeds: the S.A. Merino group having a higher proportion of the W-6 type long chain fatty acids. (Other data not presented here indicated that this was probably due to

differences in diet selection in the field). From a human nutritional point of view, the major difference was that the S.A. Merino meat provided less saturated fat. Since the cholesterol content of both breeds was similar, the ratio of triglyceride to cholesterol in meat from Dorset cross animals was two to three times that of that in S.A. Merino animals.

Plasma cholesterol concentrations of pigs consuming the cereal and meat diets were low. After consumption of the high fat meat diet there was a substantial increase in plasma cholesterol which was largely in the HDL fraction. Diersen-Schade's group in 1985 found similar increases in HDL cholesterol in pigs fed high fat diets. In the present experiment, no difference was found between the low fat meat and cereal based diets, so it might be inferred that at low levels of fat intake the effect of the source of dietary protein was minimal. Thus plasma lipid levels in pigs fed meat diets were primarily influenced by dietary fat both in terms of saturation and total calories.

The present experiment demonstrated that the nature of the protein had little significance in determining plasma cholesterol at this level of feeding. This statement goes against the proposition of Carroll, Huffs and Roberts (1979). They stipulated that protein from animal origin was intrinsically more atherogenic (due to increased plasma cholesterol) than that of plant origin. Despite their controversial findings, the effects of type of dietary fat and protein on plasma lipids might be influenced by other dietary components and level of intake.

Although the differences in plasma lipids were unrelated to any differential effect on body weight, the differences observed in the current experiment were due to the direct effects of the fat content of the various diets on plasma lipids. Thus it appears that lean red meat (low fat meat diet) is as effective as a cereal diet alone in lowering plasma cholesterol. Any lipid elevating effect of a meat based diet is substantially a function of its fat content, more specifically the saturated storage compartment.

6.3 EXPERIMENT 3b) : EFFECTS OF W-3 AND W-6 MEATS ON THE PLASMA CHOLESTEROL OF PIGS

6.3.1 Experimental Procedure

6.3.1.1 Fatty Acid Composition of Muscle Samples of Sheep Fed Linseed/Lucerne Diet and Lucerne/Oat Diet

Muscle samples were taken from sheep fed linseed/lucerne (250g/400g) and lucerne/oat (50/50 mixture - 800g). The animals were sampled with a biopsy needle as described in Chapter 3. The fatty acid extraction was done by the use of the chloroform:methanol method as described in Chapter 3 also.

6.3.1.2 Diets

Meat provided from sheep fed linseed/lucerne (W-3 meat) and lucerne/oat (W-6 meat) from Experiment 2, was incorporated into different diets fed to pigs. The diets were as follows:

(i) Diet 1 : W-3 meat (300g) and barley (700g);

(ii) Diet 2 : W-3 meat (300g) and linseed (25g) and barley (700g);

(iii) Diet 3 : W-6 meat (300g) and barley;

(iv) Diet 4 : W-6 meat (300g) and safflower seed (25g) and barley (700g);

(v) Diet 5 : mix of W-3 and W-6 meats (250g) and saturated fat (50g) and barley (700g);

(vi) Diet 6 : pig pellets (1000g).

Diets were fed to pigs in latin square designed experiment. Total lipid was extracted from each and its content determined. The major fatty acids of the meat-based diets is shown in Table 14a. The fat intake of the pigs is also reported in Table 14b.

6.3.1.3 Animals

The animals used were 6 pigs of Kangaroo Island strain. Each pig received each diet for a period of 2 weeks. Throughout the experiment the average live weight was 60kg.

6.3.1.4 Measurements

At completion of each period, the pigs were fasted for 16 hours and 20ml blood sample were taken from the

jugular vein and collected into ice-cold tubes containing heparin as an anti-coagulant. Plasma was removed after centrifugation and stored at -20°C until analysed for total cholesterol. Cholesterol was determined by gas liquid chromatography (GLC) as mentioned in the previous experiment.

The results were subjected to an analysis of variance appropriate to the experimental design.

6.3.2 Results

6.3.2.1 Fatty Acid Composition of Sheep Fed Different Diets

The fatty acid compositions of wethers fed linseed/lucerne or lucerne/oat diet were summarised in Table 15. The major saturated fatty acids (C16:0 and C18:0) remained similar in both diets.

The major mono unsaturated fatty acid (oleic acid C18:1W-9) differed between diets was significantly higher within lucerne/oat animals compared with that of the linseed/lucerne animals ($P<0.05$). The polyunsaturated fatty acid, linoleic (C18:2 W-6) appeared to be slightly higher in the linseed/lucerne samples than lucerne/oat animals, however no difference was recorded ($P>0.05$). But linolenic acid

TABLE 14

FAT INTAKE OF PIGS FED DIFFERENT DIETS a) AND MAJOR FATTY ACIDS OF W-3 MEAT BASED DIETS AND W-6 MEAT BASED DIETS b)

a) FAT INTAKE

DIET FAT INTAKE	DIET 1	DIET 2	DIET 3	DIET 4	DIET 5	DIET 6
Fat intake (g/day)	76.4	94.2	74.0	91.8	117.9	40.0

b) MAJOR FATTY ACIDS OF MEAT BASED DIETS

DIET	DIET 1	DIET 2	DIET 3	DIET 4	DIET 5	DIET 6
Fatty acids						
16:0	26.2	21.3	28.3	22.7	25.40	
18:0	19.0	14.9	20.8	20.2	28.76	
18:1 W-9	43.1	39.6	44.1	40.5	37.02	
18:2 W-6	1.7	4.7	0.8	9.1	1.1	
18:3 W-3	2.1	12.0	0.4	0.5	0.6	
P/S	0.08	0.44	0.02	0.21	0.03	
W-6:W-3	0.82	0.4	1.90	17.2	1.7	

TABLE 15

FATTY ACID COMPOSITION OF THE PHOSPHOLIPID OF MUSCLE SAMPLES TAKEN FROM WETHERS FED A LINSEED/LUCERNE DIET AND LUCERNE/OAT DIET

FATTY ACIDS (% TOTAL)		LINSEED/LUCERNE MUSCLE	LUCERNE/OAT MUSCLE
S	16 DMA*	7.35	7.42
S	16:0	12.68	11.10
M	16:1	2.64	2.89
S	17:0	0.00[b]	0.483[b]
M	17:1	0.41[b]	0.833[b]
S	18 DMA	3.36	4.20
S	18:0	10.92	12.13
M	18:1 (W-9)	16.17[b]	23.30[b]
P	18:2 (W-6)	18.68	16.24
P	18:3 (W-3)	7.82[a]	0.76[a]
P	20:2 (W-6)	0.564	1.117
P	20:3 (W-6)	0.370	0.764
P	20:4 (W-6)	10.28	13.38
P	20:5 (W-3)	3.30	0.67
P	22:4 (W-6)	0.50	1.09
P	22:5 (W-3)	3.36	2.50
Total W-6		30.40	32.85
Total W-3		14.98[a]	3.94[a]
P/S		1.32	1.043
W-6/W-3		2.02[b]	8.48[b]

a Significantly within same line ($P<0.01$)
b Significantly within same line ($P<0.05$)

* DMA dimethyl acetyl derivative

(C18:3, W-3) was found to be 10 times higher in linseed/lucerne fed animals than lucerne/oat animals. The difference was highly significant ($P<0.01$). Consequently the total W-3 fatty acid content of linseed/lucerne fed sheep was highly significantly different from the total W-3 of lucerne/oat fed wethers. The P/S ratios of both groups were similar. The W-6/W-3 ratios varied, with the lucerne/oat W-6/W-3 ratio being 8 times higher than that of linseed/lucerne W-6/W-3 ratio ($P<0.01$).

6.3.2.2 Total Plasma Cholesterol of Pigs Fed Different Diets

The analysis of variance of the effects of diets on plasma cholesterol of pigs did not show any variation or difference between diets ($P>0.05$). However the effect of Diet 1 (W-3 meat and barley) was analysed with respect to the other diets. The results are reported in Table 16. The plasma cholesterol level of pigs fed Diet 1 and Diet 6 (pig pellets) were low and not significantly different ($P>0.05$). Compared with that of pigs fed Diet 2 (W-3 meat and linseed and barley), Diet 3 (W-6 meat and barley), Diet 4 (W-6 meat and safflower seed and barley) and Diet 5 (mix

TABLE 16

TOTAL PLASMA CHOLESTEROL OF PIGS FED 6 DIFFERENT DIETS

DIET	PLASMA CHOLESTEROL (mmol/L)	(P<0.05)
1	1.66	a*
2	1.82	b
3	1.79	c
4	2.03	d
5	2.357	e
6	1.45	a
S.E.D.	0.10	

* Values followed by same letter were not significant. (P>0.05)

W-3 and W-6 meats and saturated fat and barley) however Diet 1 was significantly less ($P<0.05$).

6.3.2.3 Total Plasma Cholesterol and Fat Intake

Total plasma cholesterol of the pigs fed the different diets were analysed against daily fat intakes (see Table 14a). The analysis of variance showed that fat intake played a major role in plasma cholesterol levels ($P<0.001$) and contributed 86.3% of the between diet effects. While fat type (W-3 V W-6) contributed 13.0% leaving only 0.7% unexplained.

A regression analysis was carried out on the effect of fat intake of the different diets on plasma cholesterol. As shown in Figure 15, two parallel plots with common slope ($0.011 \pm .0013$) resulted but they differed in intercept by (0.218 ± 0.067). The intercept differed at the ($P<0.01$) level.

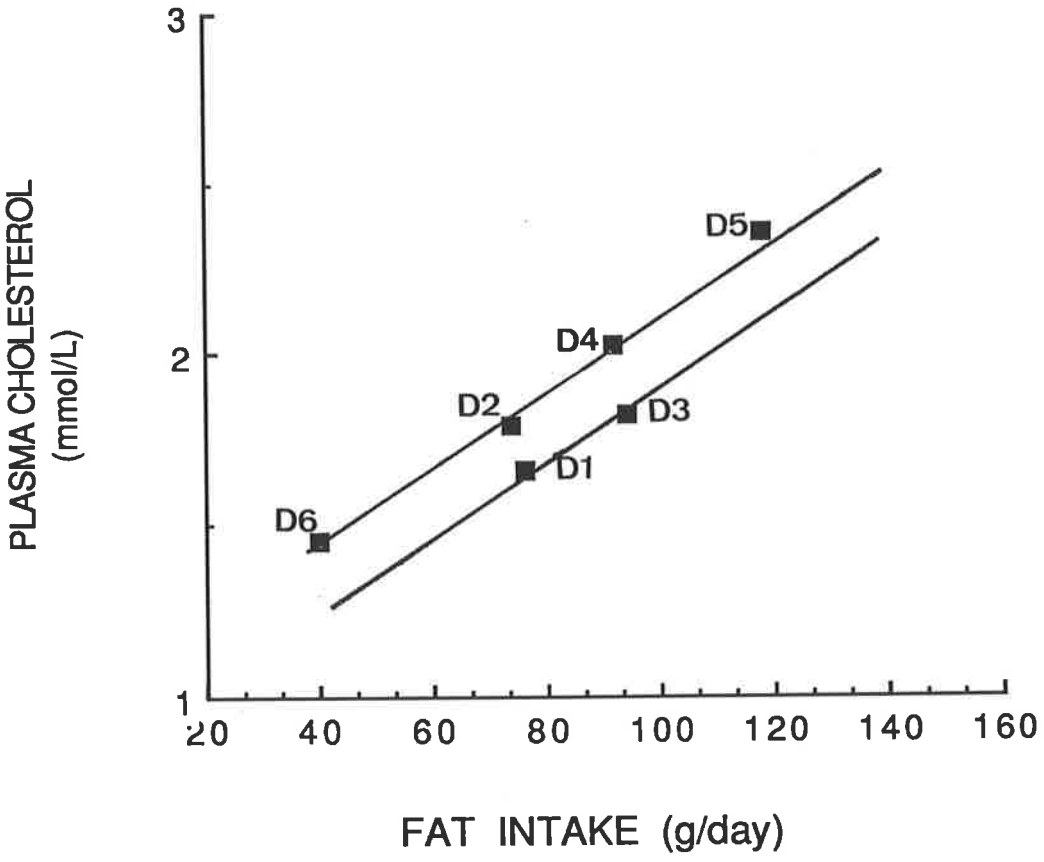
Fat intakes from W-3 meat based diets or Diet 1 and Diet 2 recorded lower plasma cholesterol, or 2/3 the level of the others ($P<0.01$).

The regression equations were as follows:

(i) For Diet 6, 3, 4 and 5, $Y = 0.011 X \pm 1.011$

FIGURE 15

THE PLASMA CHOLESTEROL OF PIGS FED MEAT DIETS FROM ANIMALS FED W-6 OR W-3 FATTY ACIDS


PLASMA CHOLESTEROL
(mmol/L)
3
2
1
20
40
60
80
100
120
140
160
D5
D4
D2
D3
D1
D6
FAT INTAKE (g/day)

(ii) For Diet 1 and 2, $Y = 0.011 X \pm 0.802$

6.3.4 Discussion

Linseed/lucerne fed wethers recorded ten times more 18:3 W-3 fatty acid (linolenic) than lucerne/oat fed sheep. The other PUFA parent (C18:2 W-6) was similar in both types. However linseed/lucerne fed animals recorded 23% less arachidonic acid (C20:4 W-6 which is a major PUFA metabolite of linoleic acid (W-6)). The results agreed with Budowski's and Crawford's (1985) statement where the role of the W-3 PUFA is viewed as a modulator of the arachidonic metabolism, by competitive inhibition by linolenic acid of the conversion of linoleic acid to arachidonic acid (which is a precursor of some prostaglandins (PG) and thromboxane (TX). Excessive production of thromboxane caused by unrestrained anachidonic metabolism can have detrimental effect on human health.

The ratios W-6:W-3 of the two groups were significantly different. The ratio W-6:W-3 of lucerne/oat fed sheep was approximately 10:1 while the linseed/lucerne fed sheep presented a W-6:W-3 ratio roughly 2:1 as found in certain wild animals (Crawford et al 1969). The ratio W-6:W-3 is a useful index

which tells the degree of competition between linoleic and linolenic acids for desaturation and subsequent incorporation. As stressed earlier, the lowering of the W-6:W-3 ratio may well have beneficial effects on human health such as lowering the incidence of coronary heart disease (CHD) (Sinclair 1985).

The plasma cholesterol of pigs fed Diet 1 (W-3 meat type and barley) and Diet 6 (pellets) was not different. An effect of meat type (W-3 meat V W-6 meat) was established. The W-3 meat based diet had similar effects in lowering blood plasma cholesterol in pigs as a fish oil based diet did when fed to rats (Balasubramaniam 1985). The present study indicates that dietary supplementation with polyunsaturated fats rich in W-3 fatty acids may bring about a reduction in plasma cholesterol in comparison to a W-6 faty acid diet. The W-3 meat diet showed a 10% lower plasma cholesterol than the W-6 meat diet. This lowering effect of 10% might be of clinical (medical) importance, as stressed by Rifkind (1987) that a 10% in reduction in cholesterol confirms a 15% reduction in coronary heart disease (CHD) risk.

Fat intake still remains the main determinant of plasma cholesterol levels and is closely related to

the risk of subsequent CHD. The present experiment showed that plasma cholesterol level was a function of fat intake, and fatty acid types (W-3 v W-6). The supply of W-3 meat diet altered plasma cholesterol level at the same fat intake. At a fat intake of 82.3g/day, the W-3 meat based diets would maintain a plasma cholesterol of 1.7 mmol/L while the W-6 diets or pig pellet diet would maintain a level of 1.9 mmol/L.

This experiment, together with Experiment 3a, demonstrates the highly significant effect of fat, particularly saturated fat, on the plasma cholesterol of a meat eating animal (including humans). Red meat protein had no effect and red (ruminant) meat cannot be regarded as a cholesterol raising nutrient. The depot and milk fats of ruminants have been 'un-saturated' by the use of 'protected' linoleic acid (Nestel et al 1974 and Mills et al 1976), but no effort was made in those experiments to lessen fat intake. As can be seen in the present study cholesterol rises with increasing fat intake and major gain in cholesterol lowering can best be achieved by lessening fat intake. A further lowering appears possible if small changes are made in altering the phospholipid polyunsaturated fatty acid to predominantly W-3 type.

CHAPTER 7. GENERAL DISCUSSION

Fat deposition in ruminants and the fatty acid composition of this depot fat and structural lipid is determined by the intake of particular nutrients and the animal's metabolic processes. In turn metabolic processes are affected by the genetic background of the animal which varies with species, genotype and breed.

Most variation in body composition in sheep is closely related to the amount of fat. Breed differences in growth rate and body composition are mainly due to differences in mature body size. The larger breeds are usually born heavier, grow faster at any age and start to fatten at a relatively higher body weight. In the first experiment reported here, the breeds studied demonstrated different growth potentials when they were raised under a common grazing strategy. The Suffolk cross breds group could be classified as "late maturing" due to the fact that they grew faster, and recorded the heaviest lean body mass of the breed groups studied. While the Dorset cross breds and the S.A. Merino breeds demonstrated similar growth potential. This observation might be attributed to similar "rate of maturing" of the two breeds although the Dorset cross bred grew more rapidly. The S.A. Merino lambs

however grew 40% more wool over the study period. Both entered the fattening phase at a lower bodyweight than Suffolk cross breds. In other words, 66% of body gain was laid down as fat whereas only 35% of gain was laid as fat in Suffolk cross bred animals at similar body weight. This observation must be taken into account when lean meat production is concerned. Selection for lean animals is synonymous with selection for less mature animals. In order to use the maturity concept, it is necessary to estimate both the weight and composition at maturity of breeds used in the prime lamb industry in Australia.

Efficiency of production can also be assessed in terms of efficiency of feed conversion. Genetic variation in efficiency depends on:

(i) the variation of feed intake;

(ii) the variation of metabolism between maintenance and growth; and

(iii) the variation in the relationship between efficiency of body metabolism and age.

Sheep production efficiency is dominated by maturity. The age at which an animal reaches maturity influences efficiency. It

declines with age as suggested by Blaxter (1964). Late maturing animals convert feed to body tissue more efficiently than early maturing animals. This was demonstrated in the present experiment by the Suffolk-cross sheep which had the highest values in terms of bodyweight and lean body mass Breed comparisons are useful when conducted on a large scale level. They provide important information for effective selection for specific purpose (e.g. lean meat production).

Apart from breed differences however it is conceivable that exogenous compounds could improve, in the short term, production and possibly efficiency of production. Anabolic agents, such as trenbolone acetate and oestradiol administrated alone or combined promote the growth of ruminants under adequate feed conditions. In the second experiment trenbolone acetate plus oestradiol (Torelor) treated wethers did tend to grow more quickly than trenbolone acetate (Finaplix) treated animals and control animals when run under optimal condition. The trenbolone acetate group showed delayed or slower growth when compared to the control animals. However the combined implant appeared to have a decreasing effect on fat deposition and an increasing effect on liveweight gain. This might be attributed to the repartitioning of energy from fat to other body components (such as lean tissues).

The effect of anabolic agents on feed intake and efficiency of feed conversion was parallel with the effect on growth rate. Feed conversion efficiency rose slightly with the use of both anabolic agents. The impact of anabolic agents on feed intake was not particularly marked. Plane of nutrition appeared to have little effect on body composition of treated and control animals.

The "red meat" industry has been forced to improve carcass quality toward leanness, due to increased public pressure for consumption of low fat meat. To a large extent the public associate meat with heart disease. This results from the fact that the consumption of saturated fat (higher in ruminants than in monogastric animals) leads to a rise in plasma cholesterol which in turn is associated with the incidence of coronary heart disease (CHD) in western society. This was partly shown the first section of the third experiment where it was shown that the consumption of fat, particularly saturated fat had a highly significant effect on plasma cholesterol of pigs. Red meat protein itself had no effect in raising plasma cholesterol. Thus a major means of lowering cholesterol is simply by consuming lean meat rather than meat high in fat. It also appears that if small changes are made in altering the structural polyunsaturated fatty acids in meat to predominantly W-3 type, then a further lowering of plasma cholesterol can be achieved.

The experiments carried out in the present study demonstrated a number of points. They were:

(i) the lamb breeds used showed differences in growth rate and body composition under field conditions;

(ii) the most common lamb used in meat production in Australia (Dorset cross breds) deposited fat at an earlier age than the other breeds, while Suffolk cross breds produced the most lean meat;

(iii) the practice of crossing British breeds with common wool producing Merinos lessens the amount of fat in the carcass by slowing down body growth rate, not by lessening perse fat content at the same body weight;

(iv) anabolic agents altered the natural composition of a particular breed;a combined oestrogen and androgenic agent implanted in wethers increased growth while an androgenic agent increased growth and also lessened fat deposition;

(v) meat from animals of different fat content when incorporated into an omnivore diet, induced cholesterol levels than were correlated to fat intake but were unaffected by meat intake;

(vi) when lambs were fed oil seed that altered the structural lipid fatty acid type, a significant decrease in omnivore cholesterol was recorded.

In conclusion , the body composition of an animal is the consequence of the interaction of nutrition with the genetic and physiological factors over a period of time .This interaction determines an animals' phenotype . Comparaisons between animals within a species or even within a breed at a given weight or age in terms of body composition or efficiency of food conversion during growth are dominated by the effctof stage of maturity . As larger mature size animals are undoubtedly less mature at a given weight and thus tend to be leaner .

Genetic variation in fatness may be exploited to produce a leaner carcass in both sheep and cattle . There is little difference between breeds in either the rate at which tissues mature ; or the percentage of fat in the body at maturity despite the fact that breeds vary in their mature size .A reduction in the proportion of fat at the same weight can be achieved by the use of late maturing breeds , either by substituting new breeds or by crossbreeding .

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