

**THE ROLE OF PROTEIN SUPPLEMENTATION
IN MANIPULATION OF BODY COMPOSITION OF LAMB**

by

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A thesis submitted in total fulfillment of the requirements
for the degree of Doctor of Philosophy

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May 2000

Declaration

I hereby declare that this thesis comprises only my original work, and due acknowledgement has been made in the text of the thesis to all other material used. This thesis is less than 100 000 words in length, exclusive of tables, maps, bibliographies, appendices and footnotes.

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May 2000

Acknowledgements

I wish firstly to thank my supervisors, Professor Adrian Egan, Dr. John Holmes and Dr. Brenton Hosking, for their support, skills and guidance throughout these studies. In particular I would like to thank Adrian for his ability to differentiate what was written from what was meant and for providing an extra set of hands when most needed from thousands of kilometers away during the re-submission of thesis.

Next I wish to thank the researchers whose collaborations and assistance enabled much of this work to be carried out: Dr Leo Cummins, Dr Janet Foot and Dr Hugh Dove at Pastoral and Veterinary Institute of Hamilton for providing facilities and teaching me the techniques in pastoral studies.

Without the help of technical staff in the field, animal house and laboratory, none of this work would have been completed. I particularly wish to thank Andre Thalen, James Wilson, Daryl Whitfield and late of Roy Thomas at Mt Derrimut, Bluey and Boots at Hamilton, Fahi in the laboratories in Parkville, Eric Ponnampalam for sharing his meat skills with me. In particular I would like to thank Andre for teaching me his precious technical experiences and giving his warm friendship during my time in Australia.

I would like to acknowledge the support of my Beloved Country throughout my studies.

I finally acknowledge my wife Schule who dared to come to Australia with me, raised the children, kept our home warm and sweet with a never-ending patience.

Thesis Abstract

In a series of indoor and outdoor experiments with young sheep, feed supplements having different protein content were investigated. The supplements were chosen as those likely to elicit different Protein:Energy (P/E) ratios in the nutrients absorbed by the animal. The objective was to identify and characterize those that would support faster growth rate, bigger and leaner carcass production for the meat market, in different seasons in Southern Victoria, Australia (35-37° South, 141-143° East). Throughout, the GrazFeed model provided a reference system chosen for prediction of performance, with which the results of grazing experiments could be compared.

Supplementary feeding experiments were undertaken in the field (Experiments 1 and 4) in seasonal periods in which the pasture base found to poorly support high growth rates of weaned lambs. These experiments were supported by nutritional studies in pens (Experiments 2, 3 and 5) and supplement effects were evaluated in terms not only of liveweight but carcass and meat characteristics. Supplements used were evaluated and selected for use in further experiments on the basis that they would provide additional metabolisable energy but also would differ in the amount and nature of the crude protein they supplied and thus deliver different balances of absorbed nutrients, in particularly different P:E ratios.

Fish meal, with a high content of rumen undegradable protein of high biological value was used in each of these experiments to provide a test of the hypothesis that slow ruminal degradation and additional protein digested in the small intestine can influence animal response. In Experiment 1 and the related pen Experiment 2, comparing a lower to a higher P (CP%):E(MJ/kg) ratio feeds (barley, 12:13 P:E ratio) to (fishmeal / lucerne meal, 1/2 w/w, 35:10 P:E ratio), barley resulted in higher fat and lower protein amounts deposited as carcass components ($P < 0.01$). The animals consuming extra protein were larger, leaner and became more uniform as a flock in terms of the range in LW and fat content at slaughter than those provided with supplements that are classed as energy feeds.

In Experiment 3 a range of alternative protein rich feeds and composite supplements was assembled that are cheaper and more readily available than fishmeal, with the

idea that different patterns of ruminal degradation, intra-ruminal N availability and amounts of RUP could be created that would be beneficial in terms of the overall animal response. The paths of rumen protein degradability was determined with nylon bag techniques, and this was used to select feeds for investigation in a field and indoor experiments, Experiments 4 and 5.

In Experiment 4, grazing animals supplemented with lupines; (P:E 32:12), fishmeal / wheat bran 1/2 w/w (P:E 35:12) and formaldehyde treatment protected sunflower meal / wheat bran 1/2 w/w (P:E 24:11) responded poorly to the supplements where quality and quantity of pasture was such that unsupplemented growth rates were predicted to be poor by the decision support model, GrazFeed. In this and the supporting pen Experiment 5, the liveweight gain, final weight and dressing percentage of all supplemented lambs were significantly better than those of control (grazing only) animals ($P < 0.05$). High and low commencing LW animals responded to protein supplements differently when these were fed at 1% BW with *ad libitum* medium quality roughage diet in indoor conditions. The heavier subgroup of fish meal / wheat bran (P:E 35:12) animals were significantly fatter than the heavy subgroup of wheat bran (P:E 17:10) animals ($P < 0.001$). Lighter subgroup of animals were leaner and became more uniform (less variable) in weight and composition as a flock. Both the heavy and the light liveweight subgroups of fish meal grew faster but were fatter at slaughter than any other sub-groups. Lightest lambs fed bran grew from 26 to 36 kg in 10 weeks and had the most suitable carcass with the lowest priced supplement tested in the experiment.

Though protein supplementation had a positive effect on lamb performance; the advantage of high RUP was not consistent or always statistically significant. Compared to the alternative protein rich feeds, fish meal showed no cost effective advantage. The consequence of this current or possible future market conditions for feeding strategies for high quality lamb production are considered.

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List of Abbreviations

ADG; Average daily weight gain.

ATP; Adenosin tri-phosphate.

BAR; barley .

BCS; Body condition score.

DM; Dry matter.

DMTP; Digestible metabolisable true protein.

DUP; Digestible undigested protein (N*6.25).

EBW; Empty body weight.

FLW; Fasted liveweight.

FM; fish meal.

FMLM; 1/2 (W/W) fish meal and lucerne meal mixture.

K_g; Efficiency of utilization of metabolisable energy for weight change.

K_m; Efficiency of utilization of metabolisable energy for maintenance.

LPN; lupines.

LW; Live weight.

MCP; Microbial crude protein.

MP; Metabolisable protein.

MTP; Metabolisable true protein.

NH₃; Ammonia.

NPN; Non-protein nitrogen.

P:E; Feed protein (g/100g DM) and energy (MJ/kg DM) rate.

PSFM; formaldehyde treatment protected sunflower meal.

PSFMWB; 1/2 (W/W) protected sunflower meal and wheat bran mixture.

RDA; Recommended daily allowance of nutrients.

RDP; Ruminally degradable protein.

RUP; Ruminally undegradable protein.

UPSFM; un-protected sunflower meal

VFAs; Volatile fatty acids.

WB; wheat bran.

YATP; Yield adenosin tri-phosphate.

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Introduction

Animal products and especially meat provides a wide range of nutrients required in a balanced diet. Almost all of the milk and about 50% of the meat consumed by humans is provided from ruminant animals. Ruminant animals have the ability to produce high quality animal protein without competing for food resources suitable for humans, as do simple stomached animals such as poultry and pigs.

With milk, meat and wool as products and opportunity for integration with intensive agricultural farming systems, there are numerous advantages of sheep as a production species. Therefore sheep production fills a logical and important niche in the economy and the ecology of human food production.

In this thesis, I have investigated the growth of young sheep and the changes in carcass composition resulting from changes in nutrition. Although differences (due to gender, age, breed, energy intake) in growth rate and carcass composition have been previously documented in lambs, the effect of extra supplied protein and the differences in performance particularly with regard to the carcass composition are poorly understood.

Fat content of sheep meat plays a major role in customers choice for reasons perceived as benefits of health (Hansen and Wyse 1990), resulting in pressure on animal producers to reduce the fatness of market lambs to meet market needs. Current markets require large and leaner lambs slaughtered younger but at greater weights.

Lamb production is influenced by a variety of factors including breed, age, nutrition, sex effects, production strategies and growth promoting agents. Genetic differences have large effects on growth rate, mature body size and composition of carcass. Interpretation of carcass composition differences of genotypes involves attention to variables such as age, growth path, weight attained and weight relative to productive mature body size.

Genetic gain (as a result of selection), have thus required more attention to environmental factors so that genetic potential to meet market specification can be

more clearly approached. Nutrition and management practices effects in altering rate of growth, carcass weight and leanness. Among the technologically possible production strategies some are not adapted, because the biotechnological practice (i.e. use of hormonal growth promoters and partitioning agents) are viewed adversely by the consumers.

The qualities as well as quantity of dietary protein play a major role in not only in providing essential substrates, but controlling growth and co-ordinating nutrient partitioning between body components (Ørskov 1992). In ruminants, carcass composition may not be as easily manipulated as it is in non-ruminants (e.g. pigs as reviewed by Hays and Preston 1994, Cameron 1990, Elsley et al. 1964) because of the fibrous nature of feeds and the effects of the fermentation process in altering nutrient balances. However, the effect of diet on body composition and the ability to manipulate fatness altering protein intake has been adequately demonstrated by scientists and by producers.

The hypothesis underlying the work reported in this thesis is that high producing ruminants such as fast growing lambs require and respond to extra protein in their diets. The conditions under which the hypothesis is tested are defined in terms of: a.) the current production environment, particularly the pasture conditions, b.) the age / weight / growth path of lambs and c.) the nature of the supplement / protein source provided, in terms of rumen degradation characteristics.

In Experiment 1 (reported in Chapter 2), supplementary feeding of young sheep with high protein or high ME content feedstuffs were provided under grazing conditions of poor pasture quality during summer / autumn period was investigated for effects on growth rates with lean body composition.

Experiment 2 (reported in Chapter 3) was designed to examine the effects of protein or energy supplements selected to provide protein and P:E ratio conditions that would differ because of different degradability of protein sources, to investigate further the conditions in which growth and carcass composition effects will occur an experiment was designed and conducted under a more controllable indoor conditions. The aim was to raise animals to 40-45 kg LW from 25-30 kg in a 10 weeks period.

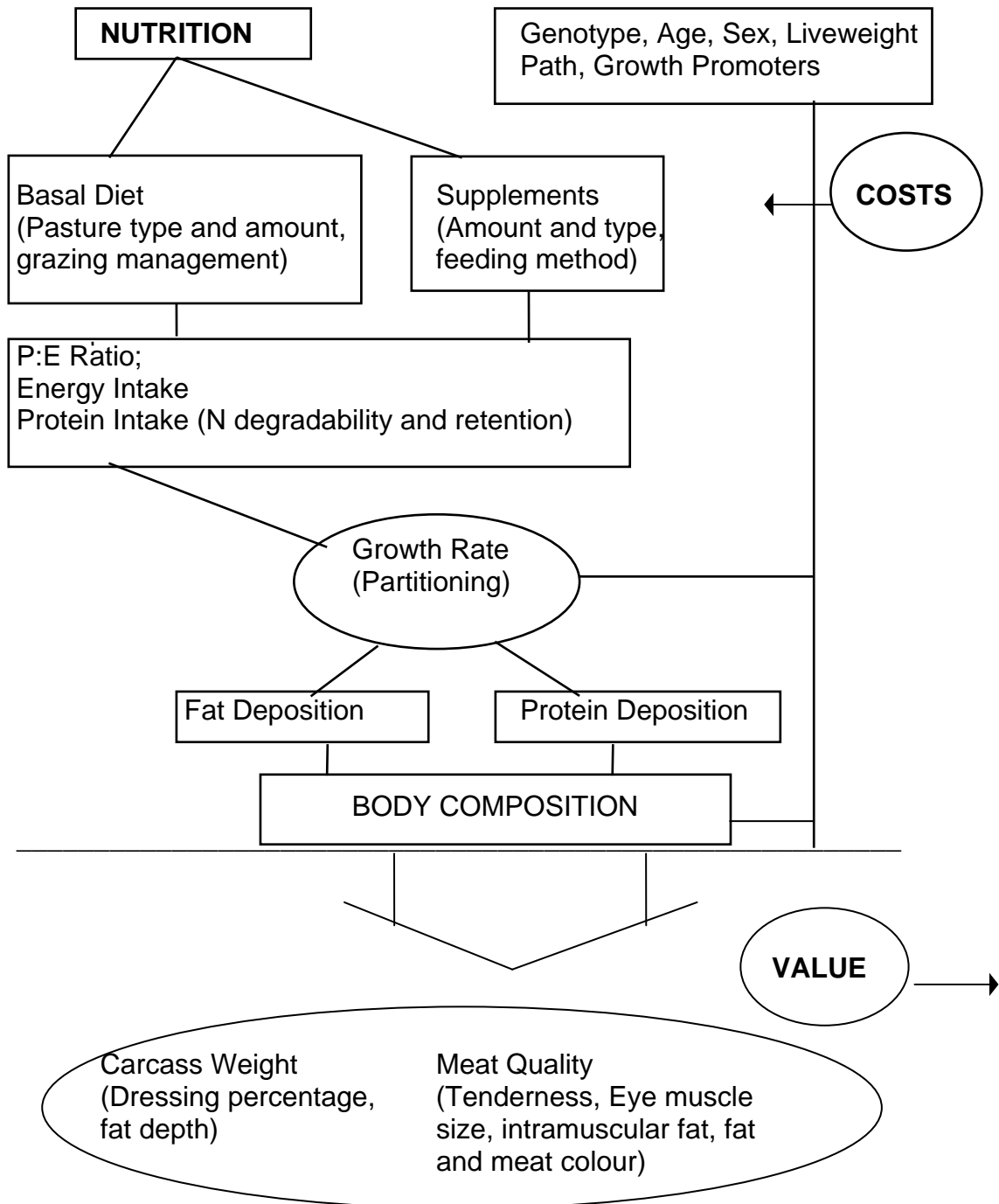
In Experiment 3, (reported in Chapter 4), nylon bag studies were conducted and were instrumental in identifying potential protein supplements with differing rumen degradability characteristics. The experiment was undertaken to evaluate specific protein-rich feeds, to provide a basis for classifying them according to likely performance as feed components and identify those suitable for further study of supplements in developing a strategy for supplementary feeding of young meat sheep

In experiment 4 (Chapter 5), feeds containing high metabolisable protein in both RUP and RDP forms were selected from those described in Chapter 4 (lupines, fishmeal / wheat bran mix. and protected sunflower meal / wheat bran mix.). They were examined for effectiveness as supplements to pastures in early winter, for young animals having high P:E ratio requirements. The scenario was one of a series that focused on growing weaned lambs to target weights for the lean lamb market, considering the seasonal changes in pasture conditions throughout the year. The major yield parameters were liveweight gain, condition score, carcass weight and carcass fatness.

Experiment 5 (reported in Chapter 6) was designed to further examine to detail the responses in growth and carcass composition of young early weaned sheep offered a good quality base diet in controlled indoor conditions. The digestibility of the feed, the liveweight gains and carcass characteristics have been measured and, the responses to protein supplements has been examined for supplements calculated to provide different P:E ratio with the presence of high MP. This has been extended to consider the effectiveness and economic benefit of specific supplements (i.e. different protein sources) on the basis of cost per unit carcass gain.

In Chapter 7, final conclusions and a perspective on market factors and financial situations affecting likely the benefits of supplementary feeding were discussed.

Chapter One: Review of literature



Factors in the cost and value chain involved in effective use of supplements.

1.1 Importance of animal products for human nutrition

Eating is an essential process of life. Human food is generally supplied from a variety of plant or animal sources. Throughout history, the consumption of animal products, especially meat has indicated a position of nutritional advantage, social and economic prestige among people or nations (Hedrick et al. 1989).

Foods derived from plants alone generally have some limiting factors for balanced nutritional intake when eaten exclusively (Hansen and Wyse 1990, Pellett and Young 1990). In terms of the nutrients they do provide, the harvested fraction of some crops like cereal grains, roots tubers and many fruits, like the banana, present nutrients in a readily digestible form of product though often they are poor sources of well balanced protein. Other plant parts not normally harvested as human food or generated as a by-product of processing are classified as high in fibrous polysaccharides such as cellulose which are indigestible for humans and other simple stomached animals.

Most crops efficiently produce large quantities of digestible carbohydrate which are the major effective energy source in the human diet.

Supplying protein of improved quality for human nutrition through plant production is a major plant breeding objective, yet will not be accomplished without added costs in crop rotation. A further limitation is that a large proportion of land is not suitable for any form of direct food production by cropping or is unavailable for production of high protein crops. Plant production from arable land may be greater than animal production but:

1. Three quarters of the land of the world is not arable but carries plant cover utilizable under sound management, by ruminant animals
2. More than half of most crops are inedible by-products, utilizable by ruminant livestock.

The world population growth rates are critical in relation to food supply. According to FAO statistics, in 1996 one of every five people in the developing world was experiencing nutritionally inadequate or malnourished conditions.

Animal products provide a range of nutrients required in a balanced diet: proteins, fats, carbohydrates, vitamins and minerals. Red meat, milk and milk products are readily available sources of some critical nutrients likely to be inadequate in a crop-based human diet. Among these are as essential amino acids (lysine, methionine and tryptophan in particular may not be supplied in sufficient quality or appropriate balance, vitamins (B complex vitamins, A, D, E and K) and minerals (iron, magnesium, potassium, sodium, zinc and copper) (Briggs and Schweigert 1990).

The amino acid composition of animal proteins is better balanced for utilization by animals and good complement for the deficiencies of plant proteins. As a result, adequate amino acid supply can be achieved at lower total protein intakes by consumption of smaller amounts of animal protein than those required when plant proteins are used as supplements in cereal based diets.

Proteins of animal origin are therefore an efficient and satisfactory supplements for cereal proteins in the human diet (Harold et al. 1994). Meat is a concentrated source of protein of highly biological value. Meat products generally supply a key portion of the recommended dietary allowance (RDA) of protein. As the Food and Nutrition Board of National Research Council describes (NRC 1980), the RDA of protein for a grown man is 56 g/day. A normal-sized serving of cooked lean meat (app. 100g) furnishes 25-30 g of protein which is about 45 to 55 percent of the RDA (Hedrick et al. 1989).

Meat also contains fat which is a concentrated source of energy. There are some disadvantages of meat fat (Kurfeld 1994), especially intra-muscular meat fat, as going to be explained in section 1 8. 1.

1.2 Advantages of animal production

In addition to the provision of high quality nutrients:

1. Animals are the only economic means by which man can utilize with low ancillary energy cost the vast areas that are non-arable, or unused for the production of goods of high nutritional and economic value.

2. From vast quantities of some agro-industrial by-products animals produce high value products and prevent disposal or pollution problems.
3. Animals can contribute to ecological stability in plant-grazing animal systems in rotation or using failed crops, by reducing erosion, plant disease, pollution, depletion of resources, and increasing soil fertility by producing natural fertilizer.
4. Animal production can be a potential source of income other than crops and supports higher incomes and standards of living for people with little or no alternative sources.
5. Animals are still the major sources of power for cultivation or transport in some countries (Holmes 1983).

1.3 Advantages of ruminant production

Almost all of the milk and about 50 percent of the meat consumed by humans is provided from ruminant animals. The world population of domesticated ruminants which provide food and other uses to man totals nearly 2.8 billion. This number includes 1 billion sheep, 1 billion cattle, 400 million goats, 125 million buffalo, and 30 million camel, yak, llama and reindeer (Acker and Cunningham 1991).

Food producing animals, particularly ruminants, convert those plant products which humans choose not to consume into desirable, high quality human food.

Pastures represent the cheapest source of ruminant feed and support most of the production systems in operation world wide. Twenty four percent of the earth's land is recorded as permanent grasslands (FAO 1998). In addition, 11% of arable crop land and 30% of the forest landscape is also occupied by forage crops and grass (Jarrige 1989).

Simple stomached animals such as swine, poultry and domestically cultured fish require foods of the same nutrient quality, high digestibility and low fibre contents as those required by humans. Therefore these animals are competing with humans for the same resources, namely readily digestible carbohydrates, lipids and high quality

protein. The use of competing animals diverts from the food resource economy, does nothing to improve the efficiency of use of land resources, and usually increases the pressures on food production and environment stability.

In contrast, ruminant animals, both wild and domestic, have the ability to produce high quality animal protein without competing for premium arable land or for food sources suitable for humans. These abilities are related to, and influenced by the symbiotic microbiota in the complex forestomach which characterizes this order of mammals. Ruminants are well adapted to the use of plant cell-wall constituents, which is the greatest part of vegetative material available as animal food, mostly fibrous in nature and low in nutrient concentration, which is also difficult to harvest because of the structure of the sward canopy. Organic matter which is not available for digestion in simple stomached animals can be fermented by the rumen microbes, and ruminants can utilize a significant portion of this otherwise unavailable dietary energy. Since this is accomplished by the growth of micro organisms, there is a concomitant synthesis of cell protein with a relatively good balance of amino acids in the rumen. In this way, the functioning ruminant animal is able through ruminal symbiotism to become a 'primary' source of amino acids and other valuable nutrients for the food chain in addition to plants.

As described and explained in detail in nutritional textbooks (e.g. Church 1972 and 1979, Ensminger et al.1990, McDonald et al.1991), there are two important adaptations which make ruminants advantageous in the food chain: first; the modification of the lips, tongue, jaws and teeth which improve the efficiency of the plant harvesting process, and secondly, the development of the digestive system in which symbiotic anaerobic cellulolytic bacteria grow. Both adaptation contribute to the effective use of herbage. The microbial population is responsible for breaking down the plant fibre and cell walls which otherwise would be unaffected by normal mammalian digestion. This process depends on a compartmentalized forestomach in which food is held for fermentation before the processes of true degradation in the abomasum and small intestines. The major characteristics in protein and energy assimilation, unique to ruminants and other herbivores that have significant fermentation in the foregut (Figure 1. 2), that must be considered are:

1. Extensive proteolysis and protein synthesis occurring prior to the major digestive and absorptive sites.

The process whereby poor quality plant protein or even non-protein nitrogen is converted to the high quality protein in ruminant animal product is complex, energy demanding and considerably less efficient in terms of nutrient and energy flow, than is the process of protein utilization in simple stomached animals, including poultry and fish.

There are some disadvantages of ruminal fermentation. The main disadvantage of forestomach fermentation is that feed constituents which do not need to be fermented, such as the soluble carbohydrates and proteins in fresh young grasses or in plant seeds are fermented and some of the digestible energy is lost unnecessarily (6-15 % methane, 6-7 % heat) (Ørskov 1987).

Many of rumen bacteria ferment protein. Fermentation of protein yields ammonia and a mixture of organic acids. Some of the ammonia is used by the bacteria to form new protein in their cells and some is absorbed from the rumen and excreted as urea. The bacteria are digested in the further compartments of the digestive tract. Because the cell wall and the membrane proteins are relatively undigestible, at least when a low residence time in the intestines, some of these bacterial protein is not digested much of the protein in the faeces consists of undegraded microbial cells and there may be very little protein from the diet as true undigested protein (Ørskov 1987).

Such disadvantages are partly compensated for by the fact that the food resources entering the food chain through ruminants are unavailable as direct sources of nutrients for humans. This leads to a food resource concept that when selecting nutrients for ruminants these should as far as possible be feeds not effectively used by simple stomach species. For protein supply, non-protein nitrogen (NPN) can be effectively converted to microbial protein, though some undegraded dietary protein may be increasing to gain higher P/E rates or rumen un-degradable protein (RUP) can be preferred for ruminant nutrition, as explained and investigated in further chapters.

As a conclusion, in terms of production in agriculture, the ruminant animal is the means of supplementing energy-rich staple foods without competing for those same foods, without compromising the goal of maximum use of arable land, and with minimal damage to the environment.

From these points of views, ruminant animals are efficient and productive food animals generating high quality proteins as milk and meat for human consumption.

They fill a logical and important niche in the economy and the ecology of human food production.

1.4 Advantages of sheep production

Sheep have traditionally been multi-purpose animals used for their fibre, skin, meat and milk. These animals can live in almost every place on earth except Antarctica and are adapted to eat a wide range of shrubs, grasses, forbs and lower forms of plant life.

As a grazer, the extreme pointed shape of the elongated skull of sheep and the mobile lips help in gathering vegetation into the mouth. The large gap between the incisors and the molars provides room for tongue movements associated with the collection and manipulation of plant leaves and stems. This anatomical structure makes sheep more advantageous than cattle for grazing poor pastures, limited in both vegetation mass and quality. However, both incisor and the molar teeth are subject to heavy wear because of the fibrous and abrasive nature of much plant material and its frequent contamination with soil (Hodgson 1990).

The primary products of sheep, wool, sheep meat, milk and skins- occupy a substantial share of agricultural world trade as well as having an important role in subsistence agriculture systems. Even though there is a significant increase in supply of synthetic fibres, wool supply contributes to approximately 5% of total fibre production with 2.5 million tonnes per year (FAO 1998). However, particularly in developed countries demand for natural products is rising. The international trade in sheep meat is active for both carcass and live animal sectors. World-wide lamb and mutton production is approximately 7.4 million tonnes (FAO 1998). The large quantities of milk produced in Africa and Asia are mainly for home consumption and only in the Mediterranean area is sheep milk regarded as a major commercially important sheep product (Croston and Pollott 1994). The total annual sheep milk production for human consumption by weight is 8.4 million tonnes (FAO 1998). The 1.3 million tonnes of sheepskins, particularly from lambs, is a valuable product and features significantly in world trade (Croston and Pollott 1994). Sheep also offer a

multitude of by-products used in the manufacturing of often used items ranging from cosmetics to photographic film (ASI 1998).

The integration of sheep and intensive agricultural farming in crop-livestock systems assists nutrient recycling and provides a high level of soil fertility. The resulting environmental benefits are increasingly important aspects of land management and husbandry in both developed and developing countries, the community benefits of which may outweigh the direct value of the major products -milk, meat and wool (FAO 1998).

1.5 Sheep production

A full year nutritional plan must be considered as an important component for a profitable sheep production system. The cyclical nature of sheep production requires a detailed knowledge of the animals nutritional requirements throughout the whole cycle since manipulations in one period of the year may have an effect on the performance of the flock many months later. For example the standard of nutrition before and during mating is very important to determine the number of lambs conceived. Nutrition during pregnancy determines ewe survival, placental size, foetal growth rate, the number of lambs born alive, birth weight, colostrum production and post partum survival (McCrabb et al. 1992). Milk production and lamb growth rate are highly affected by nutrition (Hall et al. 1992).

1.6 Feeding strategies, feeds and nutrients

Basic nutrient requirements of sheep includes energy, protein, vitamins and minerals which can be supplied from cereal grains, forage and silage crops, pasture and range forage, crop residues and a wide range of by products from food processing (Baldwin 1995).

1.6.1 Energy and energy feeds

Animals require energy for maintenance of body functions, temperature control and production. Energy is obtained in metabolism of absorbed digestion products of the feed constituents which include soluble (starch, sugar) and insoluble carbohydrates (cellulose), proteins and fats. The feed range includes herbage, cereal grains, crop residues and by-products from milling, oilseed or sugar industry.

Not all the energy in plants is in a form that can be used by animals, so only the energy available to the body is measured and described by ARC (1980) as metabolisable energy (ME) measured as MJ.

Energy deficiency results from lack of feed or from consumption of low quality feed usually because maximum voluntary intake is low, as well as low extraction of utilizable nutrients for kg of feed ingested. In these circumstances, low rates of synthesis of body constituents occurs in the face of maintained or increased rates of breakdown in particular mobilization of body stores of fat permits effective re-distribution of those resources so that higher priority processes can continue.

1. 6. 2 Proteins and ruminant protein feeds

Protein is an essential functional component in creating the cells of animal tissues. Protein is synthesized from amino acids which must be replenished in the face of ongoing catabolism. Protein digested in the small intestines provide a mix of amino acids for absorption, this mix being characteristics of the protein and the process of digestion. Highly concentrated protein can be supplied to sheep in feeds prepared from oilseed meals, meat and fish industry by-products. While these may not be feed components available in the natural ecosystems of ruminants, they can complement herbage based diets and greatly improve the efficiency of their use.

Relative to energy requirements, the protein requirements of sheep decrease with age. Because growing lambs produce and deposit more protein than body fat, their protein : energy requirement is higher than that of mature sheep (Black 1974).

Many sources of N can be used as protein sources by ruminant animals, as described in Section 1. 3. In recent years RUP has been found to be important as a rumen by-

pass protein which can be a necessary and more valuable source for the body than RDP (Ørskov 1976) for animals with a physiological demand for a high P:E ratio (Egan and Walker 1975). Fish meal is an ideal source of RUP with 40-50 % undegraded in the rumen but digested in the small intestine (Chalupa 1975).

Protein supplements are described as those feedstuffs which have more than 20 % protein (Ensminger et al. 1990). There are many proteins from animal, marine and plant sources available as well as non protein nitrogen (NPN) sources such as urea.

NPN compounds contain N which can be utilized by rumen bacteria (as described in Section 1. 3) and converted into protein which is digested in the further compartments of digestion tract.

Plant protein sources such as leguminous seeds like lupine, beans etc., vegetable oil industry by-products such as soy bean meal, sunflower meal, cottonseed meal etc. contain mainly RDP though treatment in processing may affect the RUP contents. Gluten meal is one of the plant protein source as a milling by-product.

Animal originated protein supplements such as meat meal, meat and bone meal, blood meal, fish meal are often high in RUP and can have a high biologic value. Since these products come from animal sources, the amino acid distribution is generally similar to dietary needs.

In recent years, protein evaluation systems of feeds have been described for both ruminants and non-ruminants based on the prediction of the amount of amino acids absorbed or available for absorption when a particular feed is fed. In the new protein evaluation system metabolisable system for ruminants is defined as metabolisable protein (MP) (AFRC 1992 – 93); this being the total digestible true protein (amino acids) available to the animal for metabolism after digestion and absorption of the feed in the animal's digestive tract. MP has two components:

1. Digestible Microbial True Protein (DMTP) is produced by the activities of rumen micro-organisms which synthesize protein from fermentable energy sources in the feed and amino acids or non-protein nitrogen from the breakdown of feed proteins in the rumen. About 0.25 of microbial crude protein is in the form of nucleic acids and thus is not protein. The Microbial

True Protein (MTP) is therefore 0.75 of the MCP. MTP is 0.85 digestible in the intestines. So that:

$$\text{DMTP(g/d)} = 0.75 \times 0.85 \times \text{MCP} = 0.6375\text{MCP(g/d)} \text{ (Equation 1)}$$

2. Digestible Undegraded feed Protein (DUP) is the fraction of the feed which has not been degraded in rumen during its passage, but can be digested in the intestines. Metabolisable Protein is therefore defined as:

$$\text{MP (g/d)} = 0.6375\text{MCP} + \text{DUP} \text{ (AFRC 1993). (Equation 2).}$$

1. 6. 3 Protein : energy ratio

The presence *protein : energy ratio in rumen fermentation substrates*, production and fermentation processes of all rumen micro-organisms are inter-related to supply energy as volatile fatty acids (VFAs), protein (amino acids), and vitamins to the host animal (Asplund 1994).

Both energy and protein sources affect the growth and efficiency of rumen bacteria. High cell yield is associated with the rapid fermentation of a carbohydrate substrate in the presence of a non-limiting concentration of NH_3 and essential peptides (Walker 1965). The relationship of cell yield to ATP synthesized in fermentation (Y_{ATP}) and to the VFA products of fermentation is variable (Walker 1965). Synchronizing the rate of ruminal degradation of protein and energy sources is beneficial in terms of microbial cell growth, the ruminal digestibilities of fibrous constituents, the overall efficiency of protein and energy utilization, and growth and production of the animal.

To expand on the concept of synchronization, rumen bacteria require sources of nitrogen, energy, minerals, vitamins and growth factors for their growth. Some of these are provided through symbiotic or depending relationships among the rumen microbial species, and thus the efficiency of growth of the population as a whole is a function of the ecosystem developed. N and energy are required in the largest quantities to stimulate vital functions. However, when an excessive amount of N is degraded faster than is matched by the energy sources available, a large portion of the excess N will be absorbed as NH_3 , converted to urea in the liver, and excreted in the urine (Figure 1. 1).

On the other hand, when an excessive amount of highly degradable energy exceeds N availability, there may be uncoupling of ATP production from microbial growth with, accumulation of VFAs, but low levels of protein synthesis.

Experience has taught investigators and producers that feeding combinations of protein and energy sources which complement each other in terms of rates and timing of rumen degradation may result in higher production. Further research has shown that in addition to the necessity of synchronizing rumen degradability of N and energy, the high producing ruminant may require extra protein which is undegradable and flows to the duodenum from where the total protein available for digestion in the small intestines as the sum of the microbial protein and rumen un-degradable protein (RUP).

A growing animal will have an optimum protein : energy ratio requirement at which it will express maximal protein gain (MacRae and Lobley 1986). Below this P:E ratio, increased protein content in the diet increases protein retention in the body and decreases fat deposition (Ørskov 1976, 87, 89, 92, Urbaniak 1995, Hassan 1986, Chen 1994). In one of the recent experiments by Ponnampalam and Hosking (1994) feeding young sheep, higher protein supplements such as lupines and fish meal resulted in greater lean carcass gain when compared to grain supplements.

1. 6. 4 Other nutrients

Minerals

Minerals are dietary essentials classified depending on their levels, greater than 100 ppm defined as major or macro-minerals (Ca, Na, Cl, Mg, P, K, S) and less than 100 ppm defined as trace or micro-minerals (Co, Cu, Fe, I, Mn, Mo, Se, Zn).

Some minerals provide a structural support (skeleton) for the body, and they take part in biochemical reactions as enzyme co-factors, substrate transport and regulation of body fluids.

In the experiments repeated in this thesis all animals were supplied with a supplementary mix of essential minerals in their feeds.

Vitamins

Vitamins are metabolically essential compounds which take part in many of biochemical reactions especially energy transactions. Grazing animals usually have an adequate supply of vitamins. Thiamine is one vitamin that may become deficient in sheep fed high soluble carbohydrate diets. Its deficiency may cause encephalomalacia in sheep and goat. Extra Vit A, D and E may be required in circumstances where animals are housed and fed conserved roughages or cereal grain as the basal diet. For this reason our indoor animals were injected with Vit A, D and E.

Growth enhancing treatments and feed additives

Growth enhancing treatments and additives have been considered useful in the recent years considering their positive effect on growth rates and productive performances (further information will be given on section 6.1.1.1). There are two major types:

Hormonal growth promotants,

Rumen function stimulators.

In the experiments reported in this thesis no promotants or rumen modifying agents have been used.

1.7 Production systems

Sheep meat production in exclusively forage based systems may offer the option of reduced cost of production but may lead to increased number of days needed to finish animals (Notter et al. 1991).

In comparison drylot production systems promote rapid lamb growth, usually achieve greater feed efficiency on a “kg of gain/kg of feed” basis and require fewer days for lambs to reach market weights. Forage based production systems are usually associated with slower liveweight gains, but the cost of gain may be less than for

drylot production systems. Current markets for large leaner lamb require animals to be slaughtered younger but at greater weights, than can usually be produced from slowly growing grazed animals. Lamb carcass characteristics are an important consideration in the choice of production system, and if the larger carcass has only more fat and not meat, this must be trimmed and the extra weight represents wasted feed. Feedlot lambs may have heavier carcasses due to more fat only, but may be more palatable due to fat, no “grass taint” and younger due to faster growth (Beermann 1995).

Raising animals on a forage based system can allow growth of skeletal and muscle tissue without excess fattening. Reduced carcass fat was observed when lambs grazed pasture after weaning before placement in drylot compared with lambs fed continuously in drylot (Arnold and Meyer 1988). However, moving weaned animals direct to the feedlot results in faster, more efficient LW growth than does feeding animals for a period of time on grass (Notter et al. 1991). This however, needs to be considered in relation to the composition and anatomical distribution of LW gain.

Comparing to a drylot system, finishing lambs on a grazed alfalfa system led to leaner carcasses at a constant live weight at slaughter (Murphy et al. 1994). In this case, the increase in carcass leanness with forage finishing was due to decreased fat production, not to increased rate of gain in lean mass. In comparing various strategies it is necessary to consider the extended period of finishing lambs in terms of extra costs, delays, and difficulty of supplying good pasture in all seasons.

1. 7. 1 Sheep production from pastures

Pasture herbage is a natural food of herbivorous animals and grazing is central to the whole ruminant animal production system.

Natural pastures exist as a result of adaptation to climate and include many species of grasses, legumes and herbs together. This adaptation sometimes limits the nutritional value of the pasture. Cultivated pastures, which are modified to provide more valuable forage for grazing may consist of single species, or relatively small numbers of species. Irrespective of its species composition, pasture growth, quality and

availability are controlled by four variables: temperature, light, moisture and plant nutrients like major minerals and trace elements.

The composition of pasture dry matter varies depending on the stage of maturity of the plants (Table 1. 1). While a young and fertilized grass can contain 300g crude protein ($N \times 6.25$) per kg DM, a very mature (after seed setting) grass pasture may contain as little as 30 g crude protein per kg DM. The crude fibre content (ranging from as little as 200g/kg to 400g/kg in mature samples) is related inversely to the protein content (McDonald 1991). The content of cellulose (200-300g/kg) and hemicellulose (100-300g/kg) increase with maturity and are increasingly associated with lignin. While for ruminants these polysaccharides are the accumulated energy sources in plants, lignification causes a decrease in the ME value at the plant (Table 1. 1).

The efficiency with which ME is used for maintenance (k_m) is little affected by plant maturity or nutritive value, but the efficiency with which it is used for body gain (k_g) is much lower and declines rapidly with decreasing digestibility (Graham 1964, Blaxter et al. 1971). There are comparatively few values of k_m and k_g for fresh pasture that are provided by direct measurement. Values of k_g are depressed in autumn (compared with spring) grass and as grass becomes more mature (Nicol 1987). Much of the data available has been derived in sheep feeding studies using isotope dilution and surgically prepared animals to evaluate processes of digestion and metabolism, and develop equations predicting ME and k_m , k_g (Nicol 1987).

Table 1. 1. Composition (g/100g DM), decline in *in vivo* digestibility and utilization of digestible energy (ME) of dried perennial ryegrass harvested at 4 stages of maturity and fed to sheep at maintenance level of intake (Nicol 1987).

Item	Young leafy	Late leafy	Head emergence	Seed setting	Change in apparent digestibility
Water soluble sugars	14	12	11	10	100-100
Organic acids	4	5	5	3	94-64
Protein	15	12	11	6	82-50
Non Protein Nitrogen	4	4	3	3	75-79
Pectin	2	2	2	2	72-35
Cellulose	21	22	24	27	92-73
Hemicellulose	16	19	19	26	93-56
Lignin	3	4	4	7	23-0
Ash	8	8	7	6	64-52
Lipid	9	8	7	5	65-43
Cell wall*	40	45	47	60	
Digestibility of DM (%)	86	83	79	62	
ME/gross energy (%)	66	61	62	52	
M/D (MJ ME/kg DM)**	12.0	10.8	10.9	8.9	
Efficiency of ME utilization for:					
Maintenance	78	76	75	74	
Growth	53	54	47	34	

* Cellulose, hemicellulose, plus lignin.

** Gross energy calculated from feed composition.

When pasture availability permits selective grazing, the diet eaten by grazing animals usually contains higher proportions of leaf and live plant tissue and lower proportions of stem and dead tissue than are found in the sward as a whole (Lynch and Alexander 1973). This means that the nutritive value of the diet selected is usually higher than that of the whole sward (Thornley et al. 1994). Preference and feed selection are both relative terms. The accessibility of plants and plant parts affect the choices made by the animal. The animal also applies the senses of sight, touch and smell in determining the choice (Arnold 1970). Sheep tend to be more selective grazers than cattle in most circumstances and young animals are more selective grazers than adults (Hodgson 1990). However, the selection differential is affected by many factors particularly herbage availability, pasture species and the stages of maturing of pasture composition. The intensity of selection by sheep for white clover in an *Agrostis-Festuca* sward is substantially greater than that for the same species in an intensively managed perennial ryegrass/white clover sward (Hodgson 1990). Sheep grazing a mixed sward frequently tend to graze some plant species and avoid others Gurung et al. (1994) observed that in grazing in a mixed sward, sheep selected a diet with more

green clover and less green grass and dry herbage. For the grazing animal, higher daily live weight gains are more common with dominant legumes than dominant pastures with grass (McClure et al. 1994) (Table 1. 2).

Table 1. 2 Effects of dietary treatment on performance of lambs (McClure et al. 1994):

Item	Orchard grass	Ryegrass	Alfalfa	Dry lot	SEM
N	20	20	20	24	-
Initial BW	25.7	24.9	23.4	24.0	0.46
Final BW	39.1	37.6	45.4	49.1	0.76
Initial BCS ¹	7.2	7.5	7.2	7.0	0.18
Final BCS*	8.6	8.7	10.2	12.2	0.18
ADG ² g	136	130	223	267	7.20
Total gain, kg	13.5	12.7	22.0	25.1	0.72

¹BCS: Body condition score. ²ADG: Average daily gain.

Because the clover plant places a higher proportion of its leaf in the upper layers of the sward than the grass plant does, the consequence is that even a completely non selective grazing will result in a more complete defoliation of the clover than of the grass. Thus the degree of utilization (consumption by sheep / growth of plant) will be greater for clover than for grass simply as a consequence of their different growth habits. This can put the clover at a competitive disadvantage in survival quite independent of any other implications of preferential grazing (Hodgson 1990).

Selection is thus an important factor in determining productivity from pastures.

1. 7. 2 Sheep production with supplementary feeding

1. 7. 2. 1 Characteristics of supplements and supplementary feeding

Desired levels of livestock performance are not always achieved when forage is consumed alone even when the mass of pasture available is high. As the pasture matures and turns into dry standing forage due to normal and abnormal seasonal condition, pasture nutrients become deficient for continued growth and optimum production from animals. At times any one of the following may be the first limiting factor to production:

Lack of overall availability of energy because of low digestibility and intake,
Insufficient fermentable N and S in the diet to support efficient rumen
function,

An imbalance in the protein to energy ratio in absorbed products, relative to
requirements depending on the physiological state or parasitic infection,

Low rate of out flow from rumen, creating distension and limiting feed intake,

Mineral deficiencies affecting the efficiency of growth of rumen organisms
and the animal (Preston and Leng 1987).

Many of these factors are interrelated. For example low N in the diet decreases
digestibility as well as resulting in a low ratio of amino acids to energy in the
absorbed nutrients. Increasing the availability of N in the diet increases the
digestibility and also the protein to energy (P:E) ratio in absorbed products because of
increased efficiency of fermentation in the rumen, and both effects lead to increased
intake of pasture (Egan 1977). Under conditions of low pasture quality (low
digestibility and low N), many farmers use grains for energy but may be wrong to do
so. It is an hypothesis underlying the work described in thesis that for young sheep to
achieve high growth rates of lean body mass, in the first instance, RDP and RUP
should be considered as a possible low input major supplement in sheep growth
systems. This is because in early growth periods of life, protein supplementation may
have a true supplementary effect on pasture utilization, and through this on growth
rate and the composition of the product (carcass).

1. 7. 3 Supplementary feeding

The importance of achieving an appropriate year round balance between the
nutritional requirements of individual livestock and the yield and quality of the
available grazing can not be overstated. Where the relationship between the seasonal
cycles of pasture growth and the animal production are poor, supplementary feeds are
used.

Five factors influence the kind and the amount (to supply stock with) of supplementary feed needed:

1. Seasonal variation in pasture growth rate within a year,
2. Stocking rate,
3. Stage of breeding or growth of animals,
4. Failure of normal pasture growth due to unusual circumstances like drought, fire, disease and abnormal seasons,
5. Weather and environmental effects on sheep and cattle such as extremely cold temperature or flood (Hinton 1994).

Supplementary feeding may be chosen not only for compensation of extremely severe conditions and survival. Controlled production may be aimed to provide animals with better performance, such as a target growth rate or weight, better conception and breeding rates, control of body composition and targeting better market value.

Supplementary feeds can be high energy or high protein feedstuffs, mineral or protein supplementation or feed additives.

The three main reasons to supplement the diets of sheep traditionally have been:

1. To compensate for insufficient amounts of pasture,
2. To repair a dietary deficiency such as protein or magnesium and permit improved LW gain,
3. To reach on time specified target conditions (weight and condition) for steps in production cycle (e.g. mating, lambing).

Supplementation of overgrazed pasture merges into 'opportunity' lot feeding with all roughage and concentrate supplied directly to the particular class of animal.

There is a fourth reason of considerable importance in meeting market specifications for meat. This is the use of supplements to modify the composition of the animal i.e. muscle/fat relationship at a given carcass weight and the distribution of fat (subcutaneous or intramuscular), which affects the quality of the meat eaten (Hedrick et al. 1989).

Due to their higher nutrient requirements, young sheep usually require greater amounts of better quality supplementary feeds in order to grow and fatten than do older animals grazing the same pastures (Gardner et al. 1993).

If a supplement has to be used at all the choice is best based on prediction of least cost for sufficient benefit. However, this begs the question ensuring from difficulties in accurately predicting production responses to individual supplements.

Supplementation of small amounts of readily soluble energy and N may improve the digestion of very poor quality herbage, and in some cases may actually serve to increase herbage intake (Egan 1977). Also feeds containing proteins which are protected from degradation in the rumen may permit greater growth and metabolism of tissues and therefore increased energy needs, and result in increased herbage intake. In both cases the supplied foods act as true supplements (Freer et al. 1988, Hodgson 1990).

Supplementary feeds may be offered to grazing animals to correct specific nutrient deficiencies in grazed herbage, to allow for general qualitative or quantitative limitations in nutrient supply, or to ensure a smooth transition from one feeding regime to another. They can be used as a regular strategic tool in grazing management.

These are a number of animal response factors that affect the benefits to be gained from feeding supplements. These include substitution effects and compensatory growth effects, both of which can diminish the overall value of the response. While improvement in animal liveweight and condition will increase productivity, it may not be economical to feed for these higher levels of production, unless the animals and or their product are very valuable. For example the value may derive entirely from timeliness in supplying animals to meet high value market specifications. The scenario established for the work described in this thesis relate to such conditions.

1. 7. 4 Substitution effect

Supplementary feeding of grazing animals may sometimes result in some reduction in herbage intake (CSIRO 1990). This phenomenon of substitution is commonly defined

as the reduction of herbage intake per unit supplement intake, usually as g/100g supplement (Dixon et al. 1993). However, the rate of substitution is itself difficult to predict and may vary depending on individual animal and pasture conditions in addition to factors affecting the type and level of supplementation (Lynch and Alexander 1973, Lynch 1992). Thus the substitution effect increases from about 35% in forages with a digestibility of 40% to a value greater than 80% in highly digestible forage (Hodgson 1990).

Supplements of high nutrient concentration are likely to enhance the efficiency of rumen fermentation in animals eating a low quality forage, but the addition of the same feed to herbage already containing substantial amounts of readily available energy may actually depress the digestion of the structural components of the diet especially cellulose by reducing pH (Hodgson 1990, Freer et al. 1988).

1. 7. 5 Compensatory growth

Compensatory growth refers to the increase in growth rate following nutritional restriction. Increasing the severity of the restriction before realimentation will result in a longer period for recovery and hence a longer period of feeding the animal (Buttler-Hogg 1984). Response of animals to compensatory growth is very dependent on factors such as the age at which the restriction is imposed, the severity of restriction and the duration of restriction (Ryan 1990, 93).

Complete compensation occurs when restricted animals have an increased rate of growth so they can be fed over a period to attain the same weight for age as animals not restricted (Thornton et al. 1979).

Partial compensation occurs when restricted animals increase their rate of growth but do not attain the same weight for age as those not restricted (Murray and Slezacek 1976).

Sometimes animals respond to a nutritional restriction with reduced growth rate and mature size with permanent stunting though Allden (1970) reviewed many experiments to conclude that this rarely occurs with post-natal restriction in sheep. Recovery after under nutrition may differ however, from that affect in

period of compensation of an essential nutrient. Malnutrition can affect skeletal size and through this body size and composition (Allden 1970).

If animals are restricted prenatally, immediately after birth and close to puberty, they are unlikely to compensate completely (Thornton et al 1979).

At the beginning of a period of compensatory growth, protein deposition increases, maintenance energy costs may be reduced and voluntary feed intake becomes greater per unit LW in both sheep and cattle (Ryan et al. 1993). During the restricted feeding period, when animals were fed below maintenance, the ratio of fat to protein mobilized was 1.1:1 for the sheep while it was 1.7:1 in the cattle, in these circumstances sheep did not compensate completely after the re-alimentary period (Ryan et al. 1993). In the same experiment, during the realimentation, liver and digestive tract were replenished first, the restricted animal increased feed intake above that of their non-restricted contemporaries, and the greater feed intake was identified as the major mechanism responsible for compensatory growth. Animals progress through a high rate of gain of lean, but subsequently continue weight gain with an increase in the deposition of fat. Considering sheep tend unable to compensate completely after the re-alimentary period, and the target is to achieve bigger and leaner lamb carcasses, young sheep should be supplemented in the period while they are depositing body protein instead of body fat. The conditions in which the composition of gain is biased towards lean tissue is an important consideration in assessing the comparative benefits of supplements, an objective of the experiments described in this thesis.

1. 7. 6 Frequency of feeding

Kinds of supplements be may a critical variable in establishing the benefits of supplementary feeding. Supplements will normally be provided by the farmer in an intermittent feeding schedule. The timing and frequency of feeding and the amounts provided at each feed can affect both the ruminal environment and feeding and grazing behavior of the animals and the variability among animals in the field.

Black (1974) cites that "if feed intake is low or the interval between feeds is large but the animal is not in a post absorptive state (starved) , infrequent feeding would produce a leaner animal".

Gibson (1981) concluded in a CSIRO publishing (1990) that, on average, liveweight gains by cattle were increased by $16.2 \pm 4.8\%$ when they were fed four or five times a day rather than once or twice, and a similar effect has been noted for frequent supplementation for sheep as well (CSIRO 1990). In contrast Fredericks et al (1986) found benefits to infrequent feeding. Gibson (1981) indicated that responses to feeding frequency occurred predominantly in young animals such as sheep less than one year old. However, this option is not practical in terms of supplement supply under field conditions unless cheap methods of rationing to individual animals are developed.

Feeds for the survival of animals in drought are commonly provided once or twice weekly. Compared with daily feeding, there is a substantial reduction in labour and a positive effect on between animal competition in making more even the access to and consumption of the feed. Fredericks et al. (1986) found that infrequent feeding of different grains in each third day did not affect the rate of live weight change in weaner sheep when compared to daily feeding. The factors that will be important in choosing feeding frequency are the level of supplement, the eating rate, the spread of feed across the feeding space, the potential of adverse effects of excessive consumption, and the degree to which the benefit relies on sustaining ruminal conditions within limits of substrate concentrations. For example infrequent feeding of larger amounts of substances like urea results in poor efficiency of use and increased exposure to risks of toxicity.

When full-feeding individuals, feeding should be frequent, more than once/day. For supplementary feeding of flocks, feed is more likely to be provided in larger allocations once or twice a week. In the experiments described in this thesis I therefore consistently followed the practice of setting the frequency of supplementary feeding at twice a week.

1. 7. 7 GrazFeed

The problems of making informed decisions on the best choice of nature and level of supplements to provide to optimize feeding costs and carcass value in raising profitability were referred in Section 1. 7. 3.

GrazFeed is a computer program that has been developed by CSIRO (1993) as a grazing management decision support system for farmers and graziers to help maintain sustainable farming systems and improve productivity of grazing stock. The program is developed to predict the intake of protein and energy and rate of LW change for any breed or age of sheep or cattle when pasture mass and botanical composition, physiological state of animal (pregnancy, lactation, wool growth and weight gain), weather conditions, and the characteristics of supplements, including cost, are defined.

Since use of GrazFeed would be to predict the response to particular supplements under the prevailing pasture conditions, in the pasture experiments described in this thesis I compared GrazFeed's predictions with my experimental results. The model may or may not be without flaw, but it permitted a currently used set of complex "best fit" calculations based on many independent experiments to be used.

GrazFeed however, does not predict the carcass composition of animals and this work was a part of large program to generate a new database on this important output.

1. 8 Meat production from sheep

1. 8. 1 Growth and Development

As an animal grows and develops from birth to maturity, continuous changes occur in its body conformation and composition. Moulton (1923) defined chemical maturity relating to the variation in mammalian composition at birth to the chemical maturity; animals born with a high water content are less mature and those with a relatively low water content more mature. He showed that there is a rapid decrease in the water content of fat free mammalian tissue and

an increase in protein and ash content from conception time to the time of ‘chemical maturity’ when the change becomes suddenly less and a practically constant concentration is reached. Organs which are most vital are formed first and thus tissue growth follows a sequential order: bone is earlier developing than muscle which in turn is earlier developing than fat (McMeekan 1941). In the appraisal of carcass composition, these three variables; bone, muscle and fat, if there is an increasing proportion of one, there must be a decreasing proportion of one or both on the remaining (Hedrick et al. 1989). However, fat is likely to continue to increase in weight beyond the time when other tissues have ceased to gain weight and are mature (Butterfield et al 1984).

Tulloch (1964) and Reid et al. (1968) examined the results for animals of the same breed and sex and concluded that body composition is determined by body weight and is virtually independent of age and nutritional history. Variations from regressions were greatest with fat and least with muscle. Similar relations were established from the weights of dissected bone, muscle and fat compared with carcass weight. Composition of any increment in body weight would differ between all body weights.

1. 8.2 Growth and meat production

As noted in Section 1. 3, all milk and more than half of the meat eaten world-wide comes from ruminants.

Both quality and quantity of meat production are related to the growth rate and liveweight path of the animal (Bass et al. 1990). The word “growth” implies a rate, an increase in size over time, which is the result of consuming feed and is set with mature size a typical of the growth rate. Growth can be measured in terms of weight of the whole body but also in weight and chemical components of its component parts, organs and tissues. The increase in the soft tissue components results from an increase in the number and/or the size of their constituent cells, the cells in turn being composed mainly of lipids, water and protein. In the case of bone, minerals are deposited as an extracellular excretion. Potential body composition at maturity and the maximum achieved rates along the growth path towards final composition are

defined by the animal's genes. In practice this potential is rarely achieved since intake is limited by physical and chemical properties of the feed and imbalances of nutrients absorbed affect the relative metabolic efficiency profiles of the tissues. Prediction of growth therefore needs to take account of the processes of ingestion, digestion and metabolism in addition to an adequate description of the animal.

The manner in which an animal's growth is dependent on:

1. The animal's drive to achieve its inherent growth target,
2. The extent to which the nutrients that the animal can extract from its feed can satisfy its needs,
3. Any effects of the environment and management system which modify from time to time availability of the requirements for the nutrients require to meet this target (Forbes and France 1993).

It is important to distinguish between true growth, which involves an increase in structural tissues such as muscle, bone and vital organs and fattening which is essentially an increase in adipose tissue (lipogenesis) (Hedrick et al. 1989).

Consumers' demand for lean meat, expressed as a wish to eat less fat in meat, for reasons of the perceived benefits to health, results in pressure on animal producers to reduce the fatness of market lambs produced. Cholesterol is a component of meat fats and high blood cholesterol levels in humans have been claimed to increase the risk of cardiovascular disease (Wood and Fisher 1990). As an energy source, excessive fat causes high caloric intake and obesity, and there is a further association with increased risks of cancer (Briggs and Schweigert 1990). Therefore in market terms we must have available the information, technology, and resources that can be used to improve the efficiency of lean lamb production.

The tissue growth of domestic animals, especially sheep, clearly demonstrates that ever-increasing rates of fat deposition occur with increasing age or growth rate of animal. Changes in nutrients absorbed from the alimentary tract modify the efficiency of protein and energy use and the distribution of their deposition as growth proceeds. Changes in the rates of body tissue growth relative to maintenance requirements of these tissues depends on substrate availability and the relative affinities of tissues for those substrates. Substantial change in nutrient provision and the avenues of utilization occur from weaning to slaughter weight or to mature size. This has been confirmed many times in growth experiments designed to characterize breed, genotype, gender, and

nutritional influences on composition of growth (Ørskov et al. 1976, Hassan and Bryant 1986, Urbaniak 1995).

Production of heavy lambs is advantageous for the sheep industry to reduce the incidence of small prime cuts and increase the efficiency during the processing phase. Thus Botkin et al. (1988) estimated that lambs 7 kg heavier would result in 28 to 49 kg more lamb (4-7 carcass / hour / butcher) being dressed per hour through a typical packing plant. An alternative calculation is that a 7 kg carcass in liveweight may represent a 25 % heavier lamb and if the slaughter and dressing rate is 400 head/hour, the equivalent of 100 extra carcasses (or 2.5 tonnes) per hour.

1. 8. 3 Factors affecting growth and body (carcass) composition

Maximum growth efficiency and production of lean lamb carcasses can be achieved with improved management strategies (Black 1974). However, these strategies have to consider both the cost of live weight gain and the additional price received for the improved carcass, these are the most important factors in lean lamb production.

In the overall economy, timeliness and continuity of the supply of consistent high quality product are further factors in the maintenance of market share, so this may influence the decision on the long term profitability of the whole enterprise.

In establishing a strategy for high economic performance under these conditions, the management variables that can be utilized include breed, sex, and management decisions such as lambing time, concentration of lambing, castration, weaning age, health care and special feeding management systems for market age and weight.

1. 8. 3. 1 Breed effect

Different sheep breeds have different carcass characteristics. Table 1. 3 presented below indicates the measurable carcass component differences between the breeds which have been compared at the same carcass subcutaneous fat proportion.

Table 1. 3. Some of growth and carcass characteristics of different sheep breeds

	Border Leicester	Dorset Down	Hampshire Down	Ile de France	N. Country Cheviot	Oxford Down	Southdown	Suffolk	Texel	Wensleydale	Approx. s.e. of Mean
Age at slaughter (days)	286	218	236	253	242	271	234	249	247	287	6
Carcass weight (kg)	19.7	17.0	17.7	18.4	18.3	19.7	16.4	19.1	18.8	20.2	0.1
Daily carcass weight gain (g)	74	86	82	78	82	79	80	84	83	74	2
M. Longissimus											
Width (mm)	57.5	55.1	56.2	57.0	57.0	58.1	55.3	58.0	57.7	58.8	0.52
Depth (mm)	26.3	26.0	25.5	27.5	25.7	26.3	25.8	26.4	27.4	26.1	0.35
Carcass conformation (15 point scale)	6.5	7.6	7.5	8.2	7.1	6.9	8.3	7.8	7.9	6.6	0.23
Tissue in carcass (g/kg)											
Lean	562	557	562	571	568	560	559	567	590	567	3.2
Separable fat	257	267	263	255	251	258	273	252	240	253	3.3
Daily tissue weight gain in carcass (g)											
Lean	40	47	45	43	45	42	43	46	47	40	1.0
Separable fat	19	22	22	20	20	20	22	21	20	18	0.57

(Kempster et al. 1987)

Considerable breed differences exist in growth rate, carcass characteristics and slaughter age of growing lambs' coming from different sires.

Beermann (1995) cites Hogue (1987) who found crossbreeding sires of large-mature size breeds like Suffolk rams with Finn Dorset ewes created approximately 50% greater empty body weight at maturity than Dorset-sired lambs reared under the same conditions. Suffolk sired lambs also consumed more feed and exhibited 28% greater ADG and 28% greater feed conversion (gain : feed) for growth than Dorset sired lambs. Carcass protein accretion rates were 27% greater and carcass lipid accretion rates were 15% less (Beerman et al. 1990). These results are not typical of all gains to be expected through cross-breeding. It is recognized that sheep breeds as a range in growth potential depending on the breeding selection program applied (LambPlan).

In our experiments, we chose Dorset-Horn, Merino and, Jonesdale cross-breeds (as described in Chapter 6), because they represent the most common meat-type animal and have higher growth rates than others. They are likely to be larger at mature body size, and compared to smaller breeds or cross-breeds can be slaughtered at a given liveweight at a younger age and have the advantage of leanness.

1. 8. 3. 2 Age effect on carcass

Age at slaughter weight is a key factor in determining body composition, and is a variable within breeds affected by the growth path achieved. The age of the individual primarily affects the proportion of protein in the liveweight gain so that younger animals always have more protein and less fat in their body (Butterfield and Tulloh 1988). Different organs and tissues of the body mature at varying rates (Hammond 1932), and therefore the relative proportions change with age. Muscle is an earlier developing tissue than fat, and bone is earlier developing than muscle (Elsley et al. 1964). Thus the ratio of fat to protein in a carcass will depend on the stage of maturity of the animal at slaughter. Blaxter et al. (1966) concluded that retention of N is more efficient in younger cattle and the composition of the gains showed that protein accounted for 30.5% of the total energy retained in the 15 week old animals and 24.8% in 81 week animals. The

effect of age of animal, and the energy and N retention as percentage of E + N provided are shown in Table 1. 4. These values will depend on the absolute level of E and protein provided but illustrate the changes when animals are fed the same diet at levels evaluated for constant rate of LW gain.

Table 1. 4. Age and nitrogen retention of young cattle (Blaxter et al. 1966).

Age (Week)	N Retention %	Energy retention %
15	43	28.1
31	37	
46	35	
81	34	26.9

While efficiency of energy retention was similar in young (15 weeks old) and old (81 weeks old) cattle, nitrogen retention declined from 43% to 34% of intake as the animal aged.

The nutritional fractional synthetic rates of protein (synthesized per unit protein percent) for lamb muscles at different ages or LW are reported by Gill and Oldham (1993) and represented in the Table 1. 5.

Table 1. 5. Fractional protein synthesis rates in different aged lambs.

FSR	Liveweight (kg)
0.223	5
0.188	4.7
0.048	12.9
0.042	17
0.039	31
0.019	45

As LW and muscle mass increase the rate at which protein is synthesized will depend on the providing nutritional conditions; but the rate of protein synthesis relative to exceeding protein mass declines. Furthermore, the maintenance energy requirements of gain of animal will be influenced by the gross protein synthesis rate.

The percentage of carcass to liveweight usually increases with an increase in the liveweight and age (Moulton 1923). Concurrent with this increase the percentages of non-carcass components such as hide, blood, stomach, intestines and liver decline (Hedrick et al. 1989). Thus a higher proportion of the body of

young animals is composed of slaughter by products than is the case in older and larger animals of the same genotype (Berg and Butterfield 1966).

1. 8. 3. 3 Sex effects on growth and carcass composition

Sex plays an important role in growth of most meat animal species, and considerable sex differences exist in growth rate and composition of growing lambs. Carcass protein accretion rates in ram lambs are up to 30% greater than those observed in ewes and wethers and lipid deposition is proportionally less (Beermann 1995). Bulls exhibit a faster rate of growth than steers or heifers, with a higher protein content and lower fat and energy content of the gain (Galbraith and Topps 1981). Most heifers gain 90 to 135 grams less per day than steers under the same nutritional conditions and are usually slaughtered at about 450 to 500 kg, while steers are usually slaughtered at 500 to 600 kg. The weight of the mature, fat free empty body, would be greatest for intact males, least for females, and intermediate for castrates (Galbraith and Topps 1981). Entire male sheep grew faster, lower in fat and energy, higher in carcass dry matter content than those of females and castrates (Morgan and Owen 1973).

The characteristic differences between male and female sheep and castration effect are shown in the Table 1. 6:

Table 1. 6. Differences among rams, wethers and ewes in growth, carcass composition and quality of meat (Galbraith and Topps 1981).

Characteristic	Comparison	Range of Values %	Most Likely Difference %
Rate of growth from birth to slaughter	Rams > Wethers	2-8	6
	Wethers > Ewes	0-10	3
Efficiency of feed conversion	Rams > Wethers	0-5	2
	Wethers = Ewes		0
Dressing percentage	Wethers > Rams	1-5	2
	Wethers = Ewes		0
Percentage of lean in the carcass	Rams > Wethers	3-21	10
	Wethers = Ewes		0
Fatness of carcass	Wethers > Rams	2-28	12
	Wethers = Ewes		0
Percentage of bone in the carcass	Rams > Wethers	1-2.4	1.5
Percentage of forequarter in the carcass	Rams > Wethers	3-4	3
Chemical composition of meat			
	Protein	Rams > Wethers	0.8
	Fat	Rams < Wethers	6-37
	Wethers = Ewes		10

Use of cryptorchid lambs became popular in the recent years especially where the cross-bred meat type lamb production is common because of the ability of cryptorchids to produce heavy and lean carcasses (Lee 1986, Hopkins et al. 1990, Lee et al. 1990). As reported by Lee (1986-1990) the carcasses of entire males and cryptorchid lambs grew faster and tended to produce heavier and leaner carcasses than those of wethers and ewe lambs. The impaired fertility of cryptorchids is an advantage of to keep both male and female lambs in the same flock. In our experiments we selected cryptorchid animals to gain higher growth rate and leaner carcass.

1. 8. 3. 4 Effect of growth promoters and metabolism modifiers on growth and body composition

Growth and carcass leanness can be manipulated and improved with the administration of metabolism modifiers and growth promoters. After dietary

administration of selected synthetic β -adrenergic agonists 20-40% increases in 6 week or less were observed on skeletal muscle growth in lamb carcasses but this resulted in a decrease in tenderness (Beerman et al. 1995). Administration of some hormones like ovine or bovine somatotrophine (ST) or growth hormone releasing factor (GHRH) improves carcass composition, ADG and feed efficiency (Juskevich and Guyer 1990). For most compounds, the human food safety evaluation involves the completion of the standard battery of toxicology tests and residue studies outlined in the 'General Principles for Evaluating the Safety of Compounds Used in Food Producing Animals' (FDA 1986) Although administration of β -adrenergic agonists and somatotropin is very effective in altering composition, implementation of such technology has not been fully accepted by producers and consumers. Thus there is a need to develop more acceptable and less invasive technologies.

Some antibiotics like ionophors or avoparcin can modify rumen fermentation and the energy chain and cause 10% liveweight gain advantage (CSIRO 1990, Hinton 1994). Synthetic compounds may give rise to residues which are not natural and may be found harmful in following years. In recent years, customers appear to prefer lambs containing no antibiotics or growth promoters. Often the customers, i.e. consumers fear that unfavourable scientific evidence being suppressed and that the use of growth promotants will have deleterious effects on either product quality or safety (Vanbelle 1989).

Growth promoters or metabolism modifiers were not used in our experiments.

1. 8. 3. 5 Nutritional effect on carcass composition

Carcass composition can be manipulated by nutrition in monogastric animals such as poultry and pig (Cameron et al. 1990) because they have high voluntary feed intakes and the pattern of the digestive physiology allows a wide variation in protein to energy ratio of the substrates reaching the sites of tissue deposition. In ruminants, carcass composition can be manipulated only under very controlled feeding conditions because the fibrous nature of feeds and the fermentation process allow only a more limited range of energy/protein ratios (Wood and Fisher 1990).

Nevertheless the effect of diet on body composition can be substantial. Manipulation of fatness by changing energy intake is limited to 5-8 % units difference in fatness at a given empty body weight (EBW), compared with the changes in composition that can be induced by altering protein content of the diet may be up to 50 % of EBW (Black 1974).

It is clear that the effects of nutrition on body composition are not simple with interactions between plane of nutrition, chemical composition of the diet, frequency of feeding and stage of maturity of the animals.

Sheep fed fibrous feeds low in protein/N content respond to provision of extra intestinally digested protein by increasing N retention. The extent of the response depended on an attendant increases in feed intake (Egan and Moir 1965, Egan 1972). Egan and Rogers (1978) however, found that this effect of protein supplement on intake was restricted to dietary circumstances where the P:E ratio could also be improved through the improvement of efficiency of microbial protein synthesis.

In recent years it has been frequently demonstrated that growth and body composition can be manipulated by altering the protein content of the diets (Black 1974, Ørskov et al. 1976, Hassan and Bryant 1986, Soeparno and Davies 1987, Petit and Castonguay 1994, Urbaniak 1995). Unfortunately, the magnitude of changes in growth and / or body composition varies substantially between studies. Understanding the reasons for variability in growth responses to changes in protein nutrition has been further complicated by apparent contradictory reports in the literature. Part of this has arisen from the difficulties of measuring or predicting with any reliability, the amino acid intake by the animal. Another factor may well be the poorly defined status of the animals used in the experiments, so that age, weight at commencement, and previous nutritional history may hold the key to the apparent contradictions.

In 1980 Agricultural Research Council (ARC) concluded from experimental evidence that body composition was not affected by growth rate and proposed that the nitrogen requirements of lambs weighing in excess of 30 kg would, in most instances, be met by microbial protein only; and that this can be derived from rumen-degradable nitrogen (RDN). While position was supported by Theriez et al. (1982), concluded that protein nutrition did have a minor effect on growth and body composition in sheep. Estimates of protein requirements were revised in 1984 by ARC on evidence

that lambs fed at or near a maintenance energy level may respond in growth rates to supplements of rumen-undegradable nitrogen (RUP). Other researchers found that only a portion of the protein requirements of fast growing young ruminants can be met by microbial protein synthesis (Egan and Walker 1975, Ørskov 1976 et al., Kempton and Leng 1979 Hadjipanayiotou 1982, Hassan 1986 and Bryant, Petit and Castonguay 1994, Urbaniak 1995). Thus to maximize performance in this stage of production, dietary protein from basal ingredients or protein supplements must escape rumen degradation and be available for absorption in the small intestine.

Soeparno and Davies (1987) found a significantly faster growth and a superior feed conversion with high protein diets however, they concluded that there were no observable effects of varying (high and low) protein : energy ratio in the diets (HP:HE; 20.7 CP/13.3MJ) or (LP:HE; 10.3 CP/13.3MJ) on body components or carcass composition which included carcass weight, dressing percentage, omental, kidney, perinephric and pelvic fat, fat thickness over the 12th rib, the dissected components of the carcass (muscle, fat, bone) and the chemical proportions of the carcass (water, fat, protein and ash). Ørskov et al (1976) found with age and liveweight range an increase in water content and a decrease in fat content of the carcass with increasing protein concentration in the diet (120 g CP/kg DM to 200 g CP/kg DM).

Other writers have shown that increasing the protein concentration in the diets may decrease fat content of carcasses. This was summarized by Cropper (1989) that "above maintenance, feeding has been found to affect growth and body composition in sheep by governing protein growth through supply of and by determining the lipid content of the empty body gain through the supply of DCP relative to the supply of ME".

Hassan and Bryant (1986) reported a response to RUP supplementation above the 1984 ARC recommendations when lambs were fed high roughage diets, that were independent of energy intake. They were comparing two different sources of RUP, fish meal and formaldehyde-treated rapeseed meal for a short period of 7 weeks. The apparent digestibility of fish meal was higher (0.66) than treated rapeseed meal (0.61) but the differences were statistically non-significant. For both RUP-consuming groups of animals, liveweight gain and food conversion ratio were better than in the

control group which had been consuming a mixture of tapioca, NaOH treated straw and untreated rapeseed meal (Table 1. 7).

Table 1. 7. Effect of diet on daily N intake, liveweight gain and food conversion ratio (Hassan and Bryant 1986).

	Control	Rapeseed M.	Fish Meal
Liveweight gain (g/day)	144	161	191
Final weight (kg)	42.7	43.7	44.1
Feed Conversion Ratio (g DM/g liveweight gain)	7.7	6.9	5.9
Rumen degradable N (g/day)	17.2	17.8	17.3
Rumen undegradable N (g/day)	2.6	8.1	7.6
Retained N (g/day) as proportion N intake	0.27	0.29	0.34

The response to RUP sources is clear. N of rapeseed meal was over protected by formaldehyde treatment (Chalupa 1975, Ashes et al. 1993) and a considerable amount of RUP passed through the intestines. With the fish meal diet, tissue amino acid was supplied above the estimated requirement but was associated with increases in live-weight gain.

Urbaniak (1995) in his experiment aiming to terminate when rams reach 45 kg LW, found fish meal the optimal source of supplemental protein, since this high quality protein underwent a relatively limited degradation in the rumen (38%) and supplied the highest quantities of available amino acids to be absorbed in the small intestine (Table 1. 8). This gave the best production results, owing to high levels of protein and energy retention (Urbaniak 1995).

Table 1. 8. Response of lambs to UDN sources (Urbaniak 1995)

	Blood Meal	Fish Meal	Soybean Meal	Casein
Initial Weight (kg)	24.8	24.7	25.1	24.9
Final Weight (kg)	45.6	45.0	45.2	45.2
Gain (kg)	20.8	20.3	20.1	20.3
Liveweight gain (g/day)	181	197	175	114
Protein deposition (g/day)	31.7	35.5	30.0	23.5
N intake (g/day)	22.1	22.4	22.6	22.4
Duodenal flow:				
Total N (g/day)	26.9	29.4	25.9	21.9
Ammonia (g/day)	0.4	0.4	0.8	1.4
Non-ammonia (g/day)	26.5	29.0	25.1	20.5

When the protein supply of sheep is marginal, some scientists have found an increase in the protein concentration in carcass when extra protein is provided on diets even where energy intake is below requirements for rapid growth (Ørskov et al. 1976). In circumstances when the protein supply is adequate, small changes in exogenous energy supply have been shown to have little or no effect on protein metabolism when the endogenous energy (adipose tissue) is adequate (Chowdhury 1995). The interpretation is that the endogenous energy (body fat) can be mobilized to meet energy requirements of protein anabolism and support gain of N and lean tissue. Soeparno and Davies (1987) reported that there was no observable effects on varying P:E ratio in the diets but some others like Ørskov (1976 et al.) have found an increase in water content and a decrease in fat content of the carcass.

In other studies on the use of supplementary protein in the non-protein form (NPN), the major part of the growth response was the attribute increased voluntary feed intake (Kempton and Leng 1979, Abidin and Kempton 1981, Marchment and Miller 1984, Yilala and Bryant 1985).

Protein supplements with a low RDP content such as fish meal increases roughage intake and weight gain of lambs generally without any differential effect on carcass fat (Egan 1977, Hassan and Bryant, 1986, Petit and Castonguay, 1994, Moreira et al. 1995).

Studies on the use of low RDP supplements in sheep have been concentrated on producing heavier and leaner lambs. Differences between breeds and sires have been reported in this Literature Review (Sec. 1.8.2.1) indicating that the potential exists for altering leanness through selection. Nutrition studies have also indicated potential for manipulation of carcass composition. Altering nutrient density and restriction of intake reduce fat content of animals (Black 1974). However, because many breed or nutrition differences are small, combinations of breed, nutrition and management practices should yield greater effects (Blackburn et al. 1991, Beerman et al. 1995). Manipulating body composition through available and developing market conditions should reduce the cost Per unit gain.

From the results of many studies (Egan 1975, Ørskov et al. 1976, Preston and Leng 1987) on poor quality feed indicate that the amount and quality of supplementary protein has a great effect on rates of growth and protein deposition by the animal. It

can also affect carcass leanness of sheep when comparisons are made between animals of the same age, but these differences are substantially reduced when comparisons are made at the same body weight (Black 1974). Tulloh (1964) and Reid et al. (1968) examined the results for animals of the same breed and sex and concluded that body composition is determined by body weight and is virtually independent of nutritional history. On the other hand Elsley et al. (1964) and Lohman (1971) contend that although the proportions of muscle and bone or of protein, water and ash have a constant relationship to the weight of the fat-free body, the amount of fat can be greatly affected by nutrition. Black (1974) analyzed results of a number of experiments and proposed that feeding of *protein deficient* but energy rich diets produces animals with more fat at a given body weight; and further that if animals are able to respond with increased growth rate when given additional dietary protein in the presence of sufficient energy to produce, that growth will be of more lean meat, ultimately determined by genetic potential. Protein deficiency in this sense may apply to all dietary circumstances where the rate of growth of lean tissue is limited by inadequacy of absorbed amino acids.

As described before in Section 1. 7, forage-based production systems offer the option of reduced cost production but take a longer time than drylot production systems.

Feeding systems that promote rapid lamb growth, such as concentrates fed in drylot usually result in greater efficiency (gain/feed). However, *ad libitum* consumption of concentrate in drylot resulted in fatter lambs than did the consumption of leguminous forages (Notter et al. 1991). Cereal supplements improve lamb performance but increase carcass fat (Chestnutt 1992). In a similar study Blackburn et al (1991) concluded that growing lambs for meat on pasture with *ad libitum* access to protein concentrate resulted in a product with less fat. These results indicated that additional profits might be obtained by grazing lambs on high quality pasture before beginning the feedlot phase. McClure et al. (1994) compared growth and body condition score of lambs grazing good quality Orchardgrass, Perennial Ryegrass, Alfalfa, and Drylot (completely supplemented) when slaughtered at the same ages, not at constant body weight. Drylot lambs showed more rapid LWG ($P < 0.01$), heavier and more profitable carcasses ($P < 0.01$), Alfalfa fed lambs were intermediate, and Orchardgrass and Ryegrass fed lambs were the poorest performers as shown in Table 1. 2. Murphy et

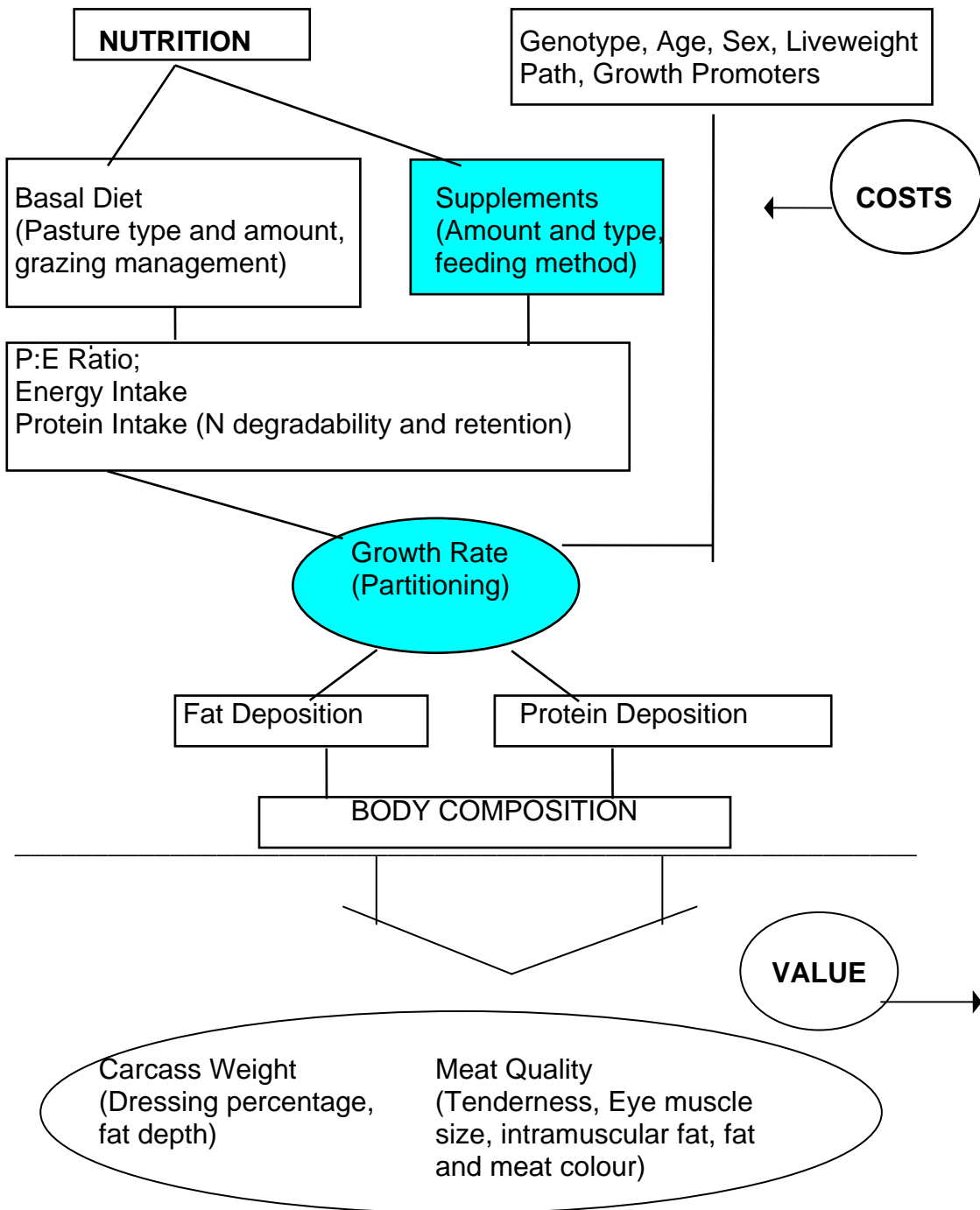
al. (1994) examined the effects of grain or pasture finishing systems on carcass composition and found daily accretion rates of lean and fat tissue were greater ($P < 0.05$) for lambs placed directly in drylot than for lambs that consume forage at the same time. In addition, daily fat accretion rates were greater in lambs in drylot than in lambs grazing forages, slaughtered at same final body weight.

Forage-fed lambs had lower daily gains and lighter carcasses than concentrate fed lambs, if they were slaughtered when concentrate-fed lambs reached market body condition. However, carcasses from lambs finished on alfalfa pasture had muscle mass not different to that of carcasses from lambs finished on concentrate diets. Lower carcass weights result on because the quantity of carcass fat was reduced for lambs grazing alfalfa. Lambs finished on grass pastures have poorer performance and carcasses with less muscle, fat, and bone than lambs finished on concentrate diets (McClure 1994).

1. 8. 3. 6 Effect of production strategies on growth and body composition

The development of an environment that will enable lambs to consume an optimal balance of pasture and agro-industrial by-products is the primary objective of most modern lamb production systems. In the US, the Cornell Star System (Hogue 1987) has shown that achieving appropriate slaughter weights and spreading the lambing season throughout the year has advantages in improved output and profitability over traditional lambing systems for the market system in U. S. A. Elsewhere a more common strategy is to rely on the judicious use of feed supplements. In Cornell Star system, the whole flock of sheep can show five lambing periods a year and high level of productivity and efficiency may be achieved with superior genotypes.

In Australia lambing seasons are synchronized considering pasture availability in most climate region with lamb production districts. This timing is mainly dependant on the strategic management plan set by farmers and their advisers and because of this there is no one Australiawide year round production system which achieves the steady supply of high quality lamb from pasture.



The supplement type and amount effect the P:E ratio undertaken by the animal and this might influence the growth rate of animal and partitioning of body components such as fat or protein deposition (Chapter 2 and 3).

Chapter Two: Responses to protein supplements in young grazing sheep, grazing mature grass dominant pasture in summer/autumn.

2.1 Introduction

Supplementary feeding becomes necessary in dry seasons when pasture availability and quality (digestibility and crude protein content particularly) decrease dramatically, reducing the ability of pasture to maintain growth of young animals or support reproduction or lactation in the grazing flock or herd.

Supplementary feeds of high protein or energy content can compensate for inadequacy of the pasture, though cost and benefit depend on the amount of supplement needed and the degree to which the supplement substitutes for pasture intake or influences of the need for selective grazing activity by the animal. Protein supplements can improve pasture intake and or balance of nutrients for more efficient energy use (Dixon et al. 1993). Origin and type of protein may effect the way in which the protein has its effect on protein turnover and deposition, and on carcass fat : lean ratio (Black 1974).

Fishmeal is a nutritionally valuable but expensive feedstuffs for all farm animals because of its high content of lysine, methionine and tryptophan, mineral and vitamins (McDonald et al. 1991). Fishmeal protein is a source of rumen undegradable protein (RUP) which is digestible in the small intestine. The extents of rumen undegradability and intestinal digestibility are variable, but some “bypass” protein will be provided, complementing the level of microbial protein flowing to the small intestine. This will increase the P:E ratio with improved availability of amino acids in proportion very valuable for young ruminant animals. Fish meal’s high biological value in young sheep nutrition was described with numerous references in the Review of Literature.

Barley is one widely available, reasonably priced supplementary grain for farm animals and has a high metabolizable energy content (ME 12-13 MJ/kg) and a crude protein content of 9-12% (McDonald et al. 1991). In many parts of the world barley is used as the main energy concentrate source in the diets of pigs and as the main

energy concentrate item in total mixed rations or as a supplement for ruminants. One problem with barley is that when used with hay or mature grass, it might adversely affect the digestibility of the roughage (McDonald et al. 1991). Part of this problem appears to be associated with pH changes, but could also occur because of low available rumen degradable N or poor timing of NH₃ availability will restrict the rate or extent of fibre digestion. Barley supplemented with urea and sulphate may produce a better environment for microbial degradation of fibre, the sulphate being potentially a factor required to support effective use of N for protein synthesis by micro-organisms (Allaway and Thompson 1966).

In this study I investigated supplement intake and production responses of young sheep to these selected supplements to provide energy and protein in different forms. The experiment was conducted in the field during summer to early autumn (January to end of March) when pasture composition and nutritional quality change with the onset of summer-autumn drought. The hypothesis was that, under these pasture conditions young sheep would respond in liveweight gain with supplements of fishmeal and barley fortified with NPN-S, and the secondary hypothesis was that initial liveweight of the animals would affect the magnitude of response.

2.2 Materials and methods

The experiment was conducted at the Mount Derrimut Field Station (144.5° East, 38° South), The University of Melbourne, Faculty of Agriculture and Forestry over an 11 week period during the season of summer - early autumn, early January to late March.

Seventy two ten month old Dorset Horn X Merino cryptorchid male crossbred lambs on a weight basis of 30 - 35 kg, grazing as a single flock were distributed by stratified randomization into three treatments and with each group subdivided into a heavy and a light sub-group (n=12). Animals were shorn at the commencement of the experiment. Rainfall throughout the experiment was recorded at the Mt. Derrimut Meteorological Station on the property. Lambs were kept as one grazing flock in a paddock of 4.5 hectares on pasture comprised predominantly of annual barley grass 45 % (*Hordeum laborinum*) and *phalaris* 30 % (*Phalaris aquatica*). Other grass and

forb species made up the remaining proportion of herbage mass. Herbage availability at the commencement of the experiment was determined as 1200 kg DM/ha (Table 2.1).

Treatments consisted of:

1. No supplement (CONT);
2. Barley grain with urea : sulphur mixture (BUS: 644 g urea + 133 g sodium sulphate make up to 1 l hot water and then mixed with 8 kg of barley);
3. Fish meal : Lucerne meal pellets (FMLM 1:2 w/w).

Pasture during the experimental period was expected to mature and senesce, resulting in reducing digestibility and protein content in the feed remaining for selection by the animals. Barley of relatively low N content was providing principally an energy source but N+S were added to reinforce crude protein value at levels that would be safe and potentially well utilized.

Twice each week at intervals of 3 and 4 days lambs including the control group were penned as treatment groups supplemented. Groups fed the appropriate supplement at rates of 350 g/head/day, and then allowed to return to pasture. During the supplementation days, animals were kept in pens for approximately two hours to finish most of the feed in troughs.

During the adaptation period of 2 weeks, as sheep were slow to adapt to the BUS treatment, and also considering the toxic levels of urea formed in lambs` rumen cause one death from the BUS group, the rate of inclusion of the urea : sulphur mixture was reduced by 50% (formulated as BUS: 644 g urea + 133 g sodium sulphate make up to 2 l hot water and then mixed with 16 kg of barley); and animals fed less N than FMLM. At the same time the FMLM supplement was poorly accepted but acceptability was improved by adding molasses at the rate of 5 % w/w.

The protein to energy rates of the supplements were, 15.5:13 for BUS and 35.2:10.3 for FMLM. The crude protein, calculated MP, dry matter digestibility and NDF values of feeds used in these series of experiments involved in this thesis study were presented in Chapter 4 in details.

Animals were weighed weekly every Tuesday at 8 AM. Condition score and fleece length were recorded in every 2 weeks.

Animals were under the respective treatment for 11 weeks after the introductory period of feed, until they reached approximately 40 kg liveweight and then were slaughtered and carcass characteristics determined.

2. 2. 1 Determination of mass of pasture dry matter

Pasture availability (Hodgson 1990) was determined at 2-3 week intervals throughout the experiment period by cutting 0.50 m x 0.50 m quadrat to ground level on a grid pattern ensuring that the four quarters of the paddock were equally represented. The samples were then weighed dried and weighed at constant dry weight. Pasture botanical composition, percentage green, bare ground and plant damage were determined by an assessment method (described below) which is recommended by Victorian Department of Agriculture (Cayley and Bird 1993).

2. 2. 1. 2 Measurement of botanical composition

A square sampling frame placed randomly (16x16cm) subdivided into four equal areas was used for a simple visual qualitative recording. The composition measured as percentage of green or dead plants in the quadrat, the areas of pasture and of bare ground were recorded with grid representations for the whole paddock.

The data was used to describe the conditions for the experiment and the changes that occurred during period. The type of data recorded was determined also by the requirements for models of pasture utilization particularly (GrazFeed, CSIRO 1993).

2. 2. 2 Body condition score

Condition score was measured at two week intervals from the start of the experiment to end and depending on the slaughter date, final condition scoring was done in 3 weeks. A relatively simple means for estimating body fat reserves by palpation of the spinal processes in sheep was provided by Russel et al. (1969). Condition scoring is simply determining the amount of fat reserves along the back and this reflects the overall fat and energy reserves of the animal. By feeling the loin area of a sheep's back, an assessment is made and a score between 1 (no fat) or 5 (very fat) given and this can be converted to percentage or kg fat by regressions based on previous slaughter studies (Russel et al. 1969). Condition scoring was carried out by the trained personnel on each sheep at each measuring time to ensure well standardized assessment and reduce operator variability (Hinton 1994, CSIRO 1990).

2. 2. 3 Fleece Length Measurement

Fleece length of animals was measured by a ruler in millimeters on the shoulder of animal in every four weeks as described by Leng et al. (1984).

2. 2. 4 Slaughter procedure and carcass analyses

Animals were stunned with captive bolt and killed by exsanguination in the Mt. Derrimut Field Station Slaughter House. After skinning and removal of head, feet and internal organs, hot carcass weight (HCW) was measured approximately 45 minutes after killing, and then carcasses chilled at 5°C for 24 hours. All carcasses were prepared, according to the AUS-MEAT standard (Anon 1990) and hung individually with an even space (2 cm) between the carcasses. Cold carcass weight (CCW) was measured 24 hours after slaughter. All measurements of meat were determined for both right and left sides of the carcass and the values were averaged prior to statistical analysis.

2. 2. 5 Eye muscle and fat depth

The area of *M. longissimus dorsi* at the 12th/13th interface (LD area) was measured by tracing onto plastic sheets (Purchas 1978). The plastic sheets were then photocopied and the images carefully cut out and weighed. The area of the muscle was calculated from the weight of standard circle cut from each blank sheet. Fat depth (GR) was measured using a vernier caliper gauge as the total fat depth at the 12th rib, 110 mm from the midline (Hopkins et al. 1993).

2. 2. 6 Sample preparation for measurement of Warner-Bratzler shear force

After the LD muscle area had been traced, samples of muscle (70-80g) were removed from each carcass at the 13th rib, placed in a polyethylene bag and frozen at -20°C until required for Warner-Bratzler shear force measurement.

Subsequently LD muscle samples were thawed at 5°C for 24 hours and trimmed of all external subcutaneous fat. Each muscle sample was placed in a plastic bag and cooked by immersion in a water bath for one hour at 80°C and then cooled in a running water for 30 minutes (Bouton et al. 1978). The cooked samples were dried with paper towel to remove excess surface moisture and held overnight at 5°C. Samples from the cooked loin were cut to a rectangular cross section (1x1x4 cm) with the fibres lying parallel to the long axis (Moller 1981) using a scalpel. Each sample was sheared at right angles to the fibre axis, using a Warner-Bratzler shear blade with a triangular slot angular cutting edge. An Instron Material Testing machine was used to measure the peak shear force (Ponnampalam 1994). An average of five measurements were taken for each sample.

2. 2. 7 Statistical analysis

Over the first 4 weeks of the experiment, the percentage of dead material of the pasture increased considerably. Pasture mass and green mass content were highly dependant on the rainfall that the decreasing green content was replenished after the heavy rainfall during February (Table 2. 1).

Table 2. 1. Pasture conditions during the experiment

Date	4.1.94	18.1.94	1.2.94	15.2.94	1.3.94	15.3.94	22.3.94	Mean
Pasture Green Content %	80	83	75	94	94	88	80	84
Pasture Mass (kg DM/ha)	1500	1800	1200	900	950	900	1050	1186
Pasture Green Mass (kg DM/ha)	1200	1500	900	850	900	800	850	1000

2. 3. 3 Supplement intakes

Lambs adjusted to the FMLM supplement more rapidly than to the BUS. At the end of first month of the experiment animals in BUS group had consumed an average of 135 g supplement/ head/ day compared with FMLM at 204 g, the difference being significant ($P < 0.05$). At the end of the experiment the average daily supplement intake of BUS fed animals was little different from than of lambs fed FMLM. However, over the whole 11 week period lambs fed FMLM, total supplement intake was about 20 % higher than those for lambs fed the BUS treatment(FMLM 21.4 kg/head v BUS, 17.2, kg/head (Table 2. 2).

Table 2. 2. Supplement intake of animals g/day/head.

Diet	Supplement Intake Total (kg/head)	Supplement Intake (g/h/day)			
		January	February	March	Mean
BUS	17.22	135	161	224	224
FMLM	21.41	204	211	230	278s

2. 3. 4 Liveweight gains

A complete summary of liveweight gain, condition score and wool length are presented in Table 2. 3. The mean liveweight gain for animals in each treatment group, the change in condition score and change in length of wool over the entire experimental period are shown on the column “change”.

Table 2. 3. Animal performance during the experiment.

	Diet	4.1.94	18.1.94	1.2.94	15.2.94	1.3.94	15.3.94	22.3.94	Mean	Change
LW (kg)	CONT	33.3	33.4	37.2	37.6	38.5	40.4	40.5		7.2
	BUS	33.3	33.9	34.4	37.6	38.9	40.6	40.7		7.4
	FMLM	33.3	34.9	35.5	39.3	40.6	42.8	42.7		9.4
LW Gain (g/day)	CONT		7	270	31	64	134	43	93	
	BUS		8	39	227	93	121	151	96	
	FMLM		39	42	271	96	156	142	122	
Condition Score	CONT	2.2	2.3	2.3	2.3	2.3	2.3	2.3	2.28	0.1
	BUS	2.2	2.2	2.3	2.4	2.4	2.4	2.5	2.33	0.3
	FMLM	2.2	2.3	2.4	2.4	2.5	2.7	2.7	2.44	0.5
Wool Length (mm)	CONT	22.3		30.4		39.6		61.7	43.91	13.51
	BUS	22.5		30.3		40.4		60.7	43.81	13.51
	FMLM	22.3		31.9		41.7		61.9	45.15	13.25

Animals on each supplement maintained stable live-weights and did not grow during the three week period of initial adaptation to supplements and feeding condition. Liveweight gain of animals increased following unexpected summer rain in late January. Differences in liveweight between supplement groups at each weighing were small and statistically non-significant. Liveweight gain of animals receiving the FMLM treatment were consistently greater but not significant than for the lambs feed BUS but final liveweight of FMLM animals was significantly ($P<0.05$) greater than for control or BUS animals which were themselves not significantly different.

Figure 2. 2. Liveweight at commencement and termination of experiment for each sheep ranked from lowest to greatest commencing weight.

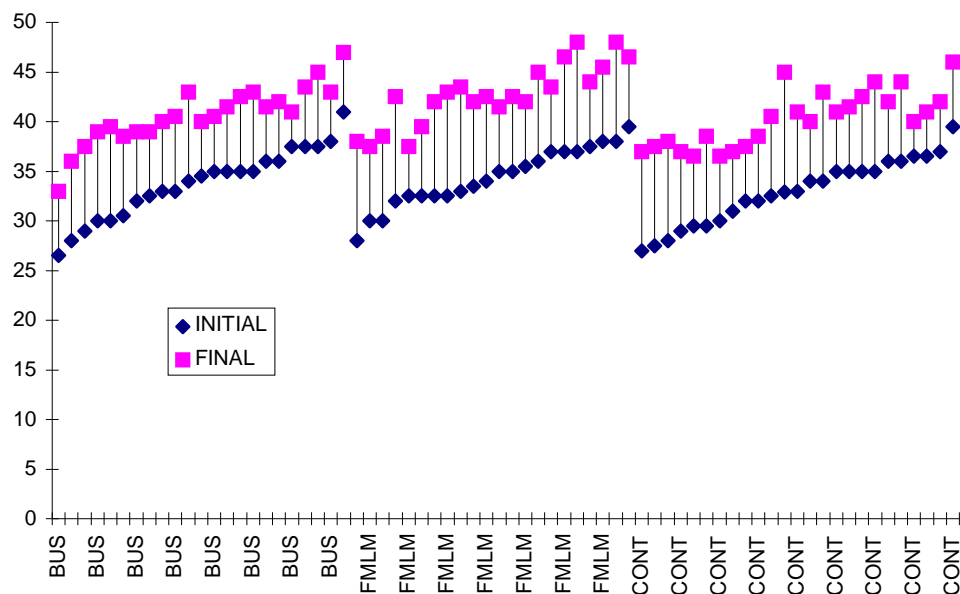


Table 2. 4. Animals mean and standard deviation divided into light and heavy sub-groups.

Supplement		Starting Weight (kg)	Final Weight (kg)	LW Gain (kg)
CONT	All animals mean	33.31	40.46	7.15
CONT	All animals SDev	3.383	2.828	0.927
CONT	Median	34	40.5	6.5
CONT	Animals < median	30.64	38.04	7.60
CONT	SDev<Med	2.341	1.376	0.984
CONT	Animals > median	36.14	42.75	6.6
CONT	SDev>Med	1.325	1.672	0.684
BUS	All animals mean	33.3	40.67	7.37
BUS	All animals SDev	3.726	2.983	1.439
BUS	Median	34	40.5	6.5
BUS	Animals < median	30.25	38.54	8.29
BUS	SDev<Med	2.179	2.169	1.322
BUS	Animals > median	36.64	43	6.36
BUS	SDev>Med	1.38	1.732	0.710
FMLM	All animals mean	33.3	42.7	9.4
FMLM	All animals SDev	3.283	3.15	1.7
FMLM	Median	33	42.5	9.5
FMLM	Animals < median	30.82	40.5	9.23
FMLM	SDev<Med	1.914	2.111	2.012
FMLM	Animals > median	35.77	45.35	9.42
FMLM	SDev>Med	2.338	1.857	1.328

2. 3. 5 Carcass weights and components

Hot carcass weights were significantly increased by FMLM supplement despite a lack of significant difference in fasted live weight. Meat quality characteristics were not significantly affected by either form of supplement. Initial and final temperatures and pH values of carcasses were the same for each treatment group. Meat colour attributes were also similar for each diet. Differences in fat depth over the 12th rib were statistically significant with FMLM supplemented animals showing greater fat depth than CONT animals. Table 2. 5 shows carcass and meat quality measurements of treatment groups.

Table 2. 5. Carcass weight and meat quality measurements of lambs fed barley and fish meal supplement.

	CONT	BUS	FMLM	Sem	P
SW	33.3	33.3	33.3	1.4	0.42
FW	40.5	40.7	42.7	1.14	0.048
FLW	38.4	39.6	40.8	1.21	0.38
HCW	16.1b	17.2ab	18.1a	0.56	0.05
GR	5.8b	7.0ab	7.8a	0.73	0.18
FLD	1.8b	2.0ab	3.1a	0.33	0.03
SFN	30.8	35.9	29.9	3.15	0.38

SW as covariate.

Abbreviations: SW: Starting weight of animals (kg). FW: Final weight (kg). FLW: Fasted live weight of slaughtered lambs; HCW: Hot carcass weight. GR: Tissue depth over 12th rib at a point 11 cm from the mid-line. FLD: Fat depth over M. longissimus dorsi at the 13th rib; SFN: Warner-Bratzler (kg) shear force (Newtons).

2. 4 Discussion

In this experiment fish meal was chosen as a supplement on the assumption that it would provide a greater content of ruminal by-pass protein for digestion in the small intestines but at this stage was not yet proven to be of low rumen degradability.

In broadest terms, the hypothesis that young sheep fed FMLM would grow more rapidly and achieve higher liveweights over the period of the experiment was supported. However, the field condition of the experiment did not meet the desired conditions. The results are discussed in relation to the initial and emerging hypothesis that led to subsequent experiments.

Liveweight gains by CONT sheep indicate that the amount and quality of pasture on offer was more than sufficient for maintenance. Weight gains of the groups were dependent on the quantity of green material on offer. GrazFeed model predictions were presented in Table 2. 6. GrazFeed predicted animals would gain 158 g/day for CONT animals, under the existing pasture conditions, animals achieved an average daily gain of 93 g/day. BUS was predicted to increase ADG to 210 g/d compared to an actual ADG of 106 g/d. For FMLM predicted and observed values were 180 g/d and 124 g/d respectively. Thus GrazFeed consistently overestimated. While this discrepancy may have arisen due to input data describing the pasture, these remains the observation that the rank order of effectiveness of supplements was reversed.

Table 2. 6. GrazFeed model predictions under the experiment conditions.

Group	Supp offer (kg)	Pasture Int.(kg)	Supp Int (kg/d)	Predicted LW Gain (g/d)	Actual LW Gain (g/d)
CONT	0	1.59	0	158	93
BUS	0.350	1.4	0.310	210	97
FMLM	0.350	1.43	0.320	180	122

The pasture intake of animals were not measured.. At the beginning of the experiment (from 4 January to 1 February) animal performance was such that the supplements appeared to cause an altered grazing behavior and possibly a supplement substitution effect. This continued up to week 4 so that during that period daily liveweight gains of the supplemented animals were lower than for CONT animals (BUS 39 g/day, FMLM 42 g/day, CONT 270 g/day). BUS was used inefficiently considering the gain / kg feed during the whole supplementary feeding period as gauged by the poorer stimulus to growth rate. This may have been due to effect of starch on fibre digestion and roughage intake (Gardner et al. 1993, Dixon et al. 1993), or to development of a lower P:E ratio and possibly because of either of these, a substitution effect on pasture intake.

Thus I initially attribute to the effects of rumen un-degradable protein supplied by the fish meal significantly better liveweight gain, higher carcass weights but greater back fat gain than in CONT animals an important input and effect not shared by BUS.

In this climatic area with a relatively long pasture-growing season depending on weather conditions, supplementary feeding during the summer-autumn had little

significant effect on amounts of liveweight gain and carcass characteristics over all treatments. The initial judgement could be that use of expensive supplements is a waste of money and labour.

However, also analysis of patterns of performance among and between treatment groups were undertaken in sub-group analysis on lambs of different starting LW classes, those <30 kg responded significantly differently to treatments, with low LW FMLM animals growing faster to higher liveweights after 11 weeks achieving a target weight of 40 kg. Low LW CONT and BUS animals did not achieve these growth rates in final weights. The benefits for growing light lambs to market weights in summer/autumn will depend on market forces and the ability to reliably meet the specification for large and leaner lamb. The larger lambs in each group also showed differences in response to the supplements. Those fed BUS did not grow any more rapidly than those receiving no supplement and achieved final liveweights that were lower than for FMLM. FMLM animals grow faster than CONT and BUS animals. These results highlight the major effect of statistical treatment on interpretation of results where there is wide variability in the commencing weights of the animals. Covariate analysis using initial liveweight terms not effectively account for all differences in responses of animals due to initial liveweight. Also this is significant practically as light lambs may well be specifically targeted for supplementary feeding to bring them to market weights. Young animals require higher P:E ratios for growth (Egan and Walker 1975, Black 1974) and grow with different body composition.

It was decided that, in later experiments sub-groups of lambs of low and high starting liveweight would be allocated as treatment groups.

The evidence of different response of animals of different weight classes arising in this experiment suggests that heavier animals perform like more mature animals and, if they grow to higher liveweights will have a higher fat content in the carcass. The lighter animals may be younger or may be lighter due to previous nutrition. In the latter case compensatory growth may be occurring, which may also be favoured by the intake and nutrient balance achieved when FMLM is the supplement. However, individual intakes were not measured and there is no evidence in this experiment of reduction in variability in LW or carcass characteristics (including fat depth)

associated with the dietary treatments as one would expect if greatest compensatory growth was occurring in the lightest lambs.

The experiment has focused attention on the conditions where the initial hypothesis needs to be made more explicit in relation to the effects of different supplements selected to provide protein and P:E ratio conditions and to investigate further the conditions in which these effects will occur, more controllable indoor conditions (Experiment 2 in Chapter 3) was designed and conducted under where individual animal intakes would be measured.

Chapter Three: Effects of high protein or energy rations on body composition

3.1 Introduction

In the previous field experiment (Chapter 2) feeding fish meal resulted in relatively higher carcass weights than were achieved with barley supplement. That experiment was carried out in late summer when it was assumed that drought conditions in Southern Victoria would result in senescence of the pastures. However, unexpected rainfall supported pasture growth and the animals response to supplements, though significantly different, were of uncertain validity. In particular, the lightest animals in the flock benefited more from BUS than did heavier animals but this was not true of FMLM fed animals which both lighter and heavier animals grew at similar rates and faster than Control and BUS animals. In the light of these circumstances it became necessary to examine the supplements in more controllable indoor conditions. The basic nutritional conditions were established using chaff as a medium quality roughage for young ruminants, and selection of young and lighter animals less than 30 kg were selected.

High protein supplements can be effective in altering the body composition as well as the rate of live weight gain of young animals (Ponnampalam 1994). For the young growing sheep, ruminal microbial protein may not be sufficient for optimal live weight gain (Egan and Walker 1975, Ørskov 1976 et al.). Newly weaned young sheep need more protein in their optimum diets for a rapid live weight gain, as described in the review of literature. Even under conditions where pasture intake was of medium quality (Chapter 2), there was evidence of a response particularly in lighter weight animals. Supplements like fish meal, which contain essential amino acids in a form that can by-pass the rumen may improve meat production both in terms of growth rate and leanness of gain.

The hypothesis for the experiment was that: “ weaned light weight lambs fed medium quality herbage will respond to a high protein (RUP) supplement with increased

growth rate and leaner carcass composition compared to those fed a high energy - low protein grain". The aim was to raise animals to 40-45 kg LW in a 10 weeks period.

The nutritional circumstances examined, aimed to produce larger and leaner carcasses from light liveweight lambs growing rapidly reach the target weight, made a comparison between two supplements, one to provide extra energy at relatively low protein content (Barley), the other to provide high protein of low rumen degradability (Fishmeal and Lucerne meal). In contrast to Experiment 1 the barley was fed without N+S addition considering how animals were slow to adapt to BUS.

3.2 Material and methods

3.2.1 Animals and treatments

At the commencement of the experiment eighteen Dorset Horn X Merino crossbred male cryptorchid lambs (av. 5 months old, 25 kg weight) were separated into 3 groups. Group 1 animals were slaughtered for initial carcass analysis after the adaptation period of two weeks to indoor and medium quality base diet feeding conditions.

The lambs from the remaining groups were allocated to individual pens for ten weeks after a two weeks of adaptation period and fed *ad libitum* with the same base diet (Lucerne chaff:oaten chaff mixture, 1:1 w/w, P:E = 11.2:7.1) and supplemented with either barley (BAR P:E = 12.3:13) or fish meal:lucerne meal (1:2, w/w P:E = 35.4:10.4) pellets (FMLM). Each supplement was fed at a level of 1% of liveweight and fed each morning at the same time.

The crude protein, calculated MP, dry matter digestibility and NDF values of feeds used in these series of experiments involved in this thesis study were presented in Chapter 4 in details.

3. 2. 1. 1 Measurements

Intakes of basal roughage and of supplement for each sheep were recorded daily and live weights measured at weekly intervals. At the end of ten weeks when they were 7 months of age and the heaviest animals weighed 45 kg, animals were slaughtered for the carcass measurements.

During the feeding period, after all animals had been on the supplements for 30 days, animals were moved to metabolism crates for a period of 10 days and a digestibility and N balance study was undertaken as described by Neathery (1972). Urine and faeces were collected daily over 10 days, subsampled, cumulatively bulked and frozen until the analysis.

The killing and carcass processing and carcass measurement methods were as described in Chapter 2.

3. 2. 1. 2 Carcass chemical analysis

About 1 month after slaughter, carcasses were removed from freezer, weighed and cut into thin sections (2-3 cm) using a band saw. The sections were sequentially ground through 5 cm and 10 mm screens and finally minced through a 2 mm screen. The minced carcass was weighed, mixed by hand and subsamples (75-100 g) stored at (-20°C). The sub-samples were later freeze dried to determine the dry matter content, then thoroughly mixed to obtain a homogeneous sample for chemical analysis.

Ash content of the carcass was obtained by a combustion in a muffle furnace at 550°C for 8 hours. Triplicate subsamples (dried; 0.5-1 g) of each carcass were weighed in thimbles and placed in drying oven (70°C) for 24 hours. On removal from the oven, all samples were re-weighed and subjected to ether extraction using diethyl ether (Savell et al. 1986). After an 8 hour extraction period, samples were removed and allowed to air to remove most of the ether, and placed in a drying oven for at least 8 hours before re-weighing. Percentage fat and ash were calculated on a dry matter

basis and the protein content determined by A.O.A.C. Methods of Analysis (1980) Micro-Kjeldahl method for nitrogen.

3. 2. 1. 3 Meat colour determination

The carcasses were cut between the 12th and 13th rib to expose the M. longissimus dorsi. The cut surface was allowed to bloom for 30 minutes. Triplicate measurements of meat colour (a is relative redness, b relative yellowness and L relative lightness) were made at the cut surface of the M. longissimus dorsi at the 13th rib (Cameron et al. 1990) using a Minolta Chromometer CR 200 with a glass light projection tube and data logger attachment. Fat colour of the rump area was measured using the same procedure.

3. 2. 1. 4 Statistical Analysis

Statistical analysis were made with Minitab in analysis of variance, one way ANOVA with LW as covariate and 2 way ANOVA with treatments and subgroups or LW.

3. 3 Results

3. 3. 1 Feed intake and digestibility

The group fed FMLM consumed more base diet and supplement than the barley fed group. Total dry matter intake (DMI) of FMLM group animals were significantly higher than the BAR group ones. Dry matter digestibility differences between animals was not significant. (Figure 3. 1 and Table 3. 1).

Figure 3. 1. Daily supplement and base diet intake of animals on a dry matter basis.

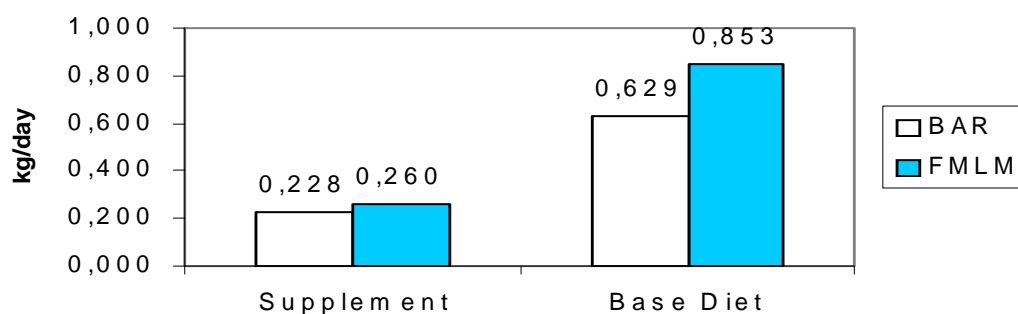


Table 3. 1. Feed intake and digestibility of young sheep fed barley grain (BAR) and fish meal pellets (FMLM) supplements at 1% LW during the digestibility trial.

	BAR	FMLM	SEM	P Value
No. Animals	6	6		
DM Intake (g/day/head):				
Supplement	256	328	9.4	0.001
Chaff	866	1110	27.4	0.001
Total	1122	1438	34.2	0.001
DM Digestibility (%):				
Chaff*	57.8	55.9	1.53	NS
Total	64.1	62.6	1.19	NS

* Chaff digestibility calculated assuming supplement IVDMD = 85% from Egan and Walker 1975.

3. 3. 2 Liveweight Gain

From the beginning of supplementary feeding, FMLM animals started growing more rapidly than BAR animals. Weekly weight results are represented in Figure 3. 2. The average live weight gain of the FMLM group was higher than for animals fed barley grain ($P < 0.005$), live weight gains of lambs fed FMLM and Barley were 235.7 and 112.9 g/d.

Figure 3. 2. Weekly liveweights (kg) of lambs fed with the same base diet, supplemented by BAR and FMLM.

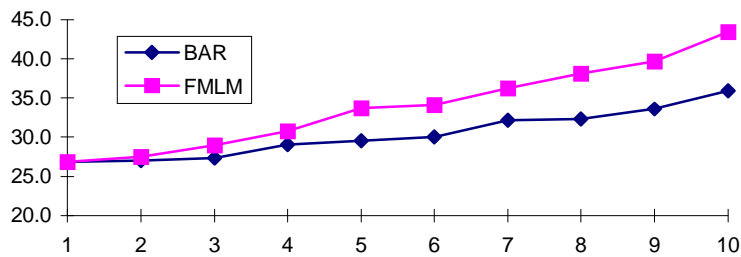
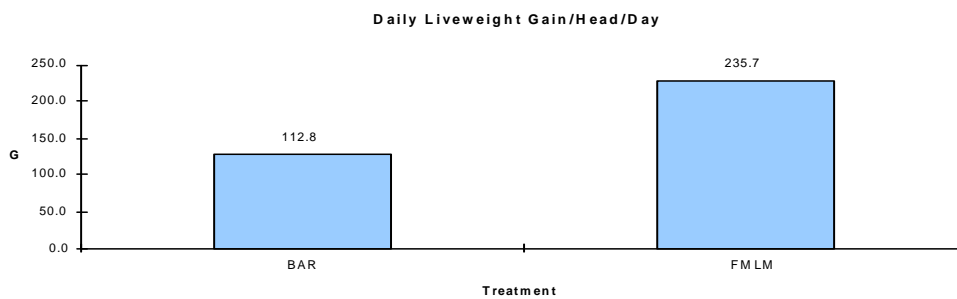


Figure 3. 3. Average daily liveweight gain of animals.



3. 3. 3 Carcass Weights and Components

At slaughter fasted liveweight, hot and cold carcass weights of animals of FMLM group were higher than BAR group ($P < 0.05$) (Table 3. 2). Empty body weights (animals starved 24 hours) of animals were significantly different between BAR and FMLM animals ($P < 0.05$). Carcass gross energy content and ash content were not significantly different amongst the treatments. Carcass protein content of FMLM animals were significantly higher ($P < 0.001$) than that of the other group. Visceral organ weights, and the fat and protein contents were not significantly different between treatment groups. Table 3. 2 shows meat and carcass quality measurements. In particular, the more rapid growth did not result in significant increase in fat thickness (GR).

Table 3. 2. Carcass weights and contents of animals.

Item	INIT	BAR	FMLM	Sem ²			
Significance							
Initial liveweight (kg)	25.5	26.8	26.8	1.73			Ns
Final liveweight (kg)	25.5	34.7	43.3	1.57			**
Gain (kg)		7.9	16.5	1.02			**
Empty BW (kg)	22.3	33.6	39.7	1.39			**
Carcass weight (kg)	10.4	15.6	18.5	0.86			*
Fat content (kg)	2.99	4.1	4.1	0.39			Ns
Protein content (kg)	1.95	2.4	3.1	0.13			**
Ash content (kg)	0.112	0.18	0.15	1.1			Ns
Visceral organ weight (kg)	3.9	6.03	7.54	1.23			Ns
Fat content (kg)	0.47	1.01	0.98	0.4			Ns
Protein content (kg)	0.59	0.82	1.13	0.29			Ns
Carcass energy content ³ (MJ)			<u>Gain</u>				
Protein	45.3	55.8	72	10.5	26.7	3.1	***
Total energy	162.3	216.4	232.6	54.1	70.3	17.2	Ns

¹Carcass weight as covariate; ²pooled sem, ³ Energy calculated as GE=(23.23*CP) + (39.19*Fat) (AFIC-CSIRO 1987)

3. 3. 4 Meat Quality of Carcasses

The differences in other meat quality factors such as meat colour and fat depth were not statistically significant between initially slaughtered animals and treatment groups (Table 3. 3).

Table 3. 3. Meat quality measurements:

	Initials	BAR	FMLM	Sem ²	P
FLW	22.3	33.6	39.7	1.67	0.03
HCW	10.4	15.6	18.4	0.085	0.04
CL	42.2	58.3	61.0	0.74	0.03
GR	3.9	7.1	8.2	0.69	0.30
ML	34	34.7	34.2	0.61	0.59
MA	19	19.9	20.7	0.39	0.18
MB	8	8.6	8.9	0.19	0.24
FA	6.6	6.9	8.8	0.85	0.15
SFN	32.1	31.6	30.9	2.46	0.85

¹Carcass weight as covariate; ²pooled sem.

Abbreviations: FLW; Fasted liveweight at slaughter. HCW; Hot carcass weight. CL; Carcass length GR; Fat depth M. longissimus dorsi. ML; Meat colour, light MA; Meat colour, ultra red MB; Meat colour, green-yellow. FA; Fat colour SFN; Warner-Bratzler (kg) shear force (Newton's).

FMLM supported greater gains in fasted liveweight and carcass weights than BAR, significantly ($P<0.05$). Fat content (kg) in the carcass was similar for each diet while protein content was increased by FMLM ($P<0.005$). Overall energy retention in the carcass was similar for both diets although FMLM resulted in significantly more (26%) energy retained as protein. At similar liveweights, variations in energy deposition in the carcass paralleled differences ($P<0.001$) in ration DM intake. DM intakes were 1.12 and 1.44 kg DM/day ($P<0.05$) for barley and FMLM diets, respectively.

3.3 Discussion

Considering the response of animals in the previous field experiment (Chapter 2) to barley (BUS) urea - sulphate mixture, the grain (BAR) itself was used as an energy source as a base for comparison.

The base diet offered to animals were expected to be in medium quality pasture (Lucerne chaff:oaten chaff mixture, 1:1 w/w, P:E = 11.2:7.1).

Animals responded to the supplements with reasonable growth rate. FMLM animals performed better (235.7 g/day) than BAR (112.9 g/day) possibly because of higher RUP in their ration as described in the Review of Literature; that may also have provided slow release N benefiting ruminal digestion and microbial growth.

For both supplement treatments, animals were within the acceptable standards for fat content in their carcasses, but FMLM animals were heavier and leaner. Other body compartments such as head and feet, and visceral organs were relatively higher for FMLM animals.

Protein per unit energy gain of the carcass was 0.18 and 0.35 for BAR and FMLM animals respectively. Thus barley produced a less stimulus to growth rate but the composition of the animal became more fat compared to the more lean animals on FMLM, a supplement calculated to support high P:E ratio in the nutrients absorbed.

Comparing to the results of the previous experiment (Chapter 2), the animals in this experiment were younger and starting at lower LW. However, over the weight range achieved animals in the experiment became a little fatter at similar liveweight. This would reflect differences in exercise or environmental effects for animals under field or intensive indoor feeding conditions when concentrate supplements are fed.

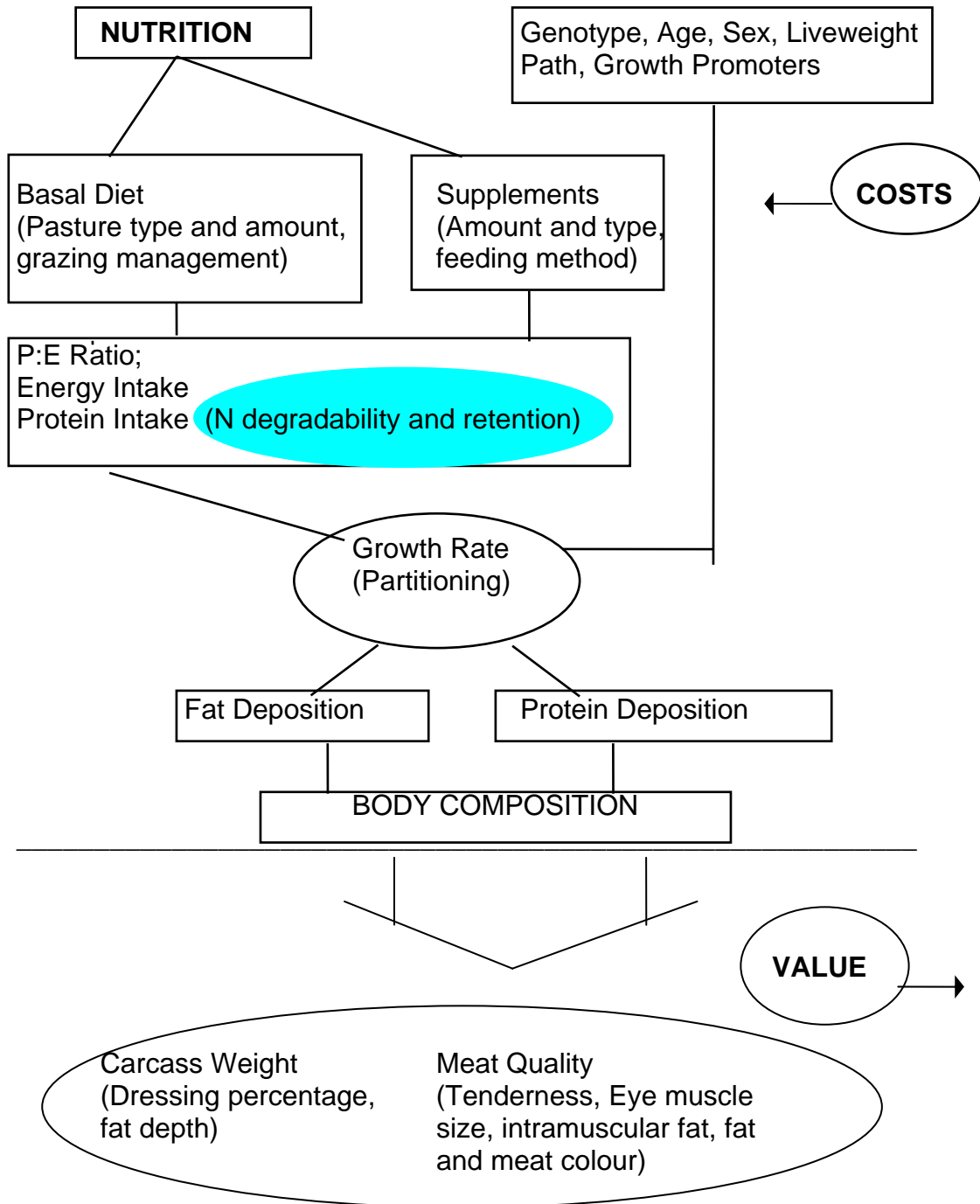
It is calculated that those animals receiving barley ingested the whole diet to provide a lower P:E ratio. This may have caused a substitution effect with the base diet intake, but certainly they were not getting a real improvement in P:E ratio as calculated for animals in the previous field experiment. On the other hand the FMLM diet might have improved ruminal roughage digestibility as described by Hassan and Bryant (1986) and Petit and Castonguay (1994) so that base diet intake was significantly higher than with BAR animals.

The results suggest the effectiveness of FMLM supplements, possibly through delivery of high RUP. The role for such supplements requires further studies since this may provide potent means for the manipulation of body growth and carcass composition through the diet.

This work has been carried forward by Ponnampalam (1996), Ørskov et al. (1976) and Kabre and Petit (1994) fish meal improves the intake of roughage if used alone as a supplement and might improve carcass composition. The mechanism is possibly by changing increasing the P:E ratio.

Though fish meal may prove useful in terms of a biological response, it will only work in certain circumstances (which we seek to define) and at relatively high cost. Further studies reported in subsequent chapters were undertaken to examine response to supplements constructed to contain protein with different rumen degradability in order to find an equally effective but possibly less expensive, more widely available supplement. Nylon bag studies were therefore undertaken to identify the potential of mixed protein sources to provide supplements with differing rumen degradability characteristics. These are described in Chapter 4.

Chapter Four: Prediction of degradability characteristics of protein-rich supplements in the rumen by nylon-bag technique.



Experiment 3 focused on degradability of protein sources alone or in mixtures designed to provide different RDN – RUP patterns that may produce positive benefit in fermentation + intestinal digestion processes.

4.1 Introduction

Crude proteins provided in ruminant feeds can supply varying amounts of N to rumen micro-organisms and to the process of intestinal digestion. Consequently protein sources for ruminants are classified according to their degradability in the rumen. Some, such as NPN sources like urea and soluble proteins in fresh young herbage are highly degradable, others such as meat meal and grain legume protein are of variable degradability depending on processing, while others like cottonseed meal and fish meal have the reputation of consistently resisting rumen degradation. The experiment reported in this Chapter was undertaken to evaluate specific protein-rich feeds, to provide a basis for classifying them according to likely performance as feed components and identify those suitable for further study of supplements in strategy for supplementary feeding of young meat sheep

As described in the Review of Literature, many proteins fed to ruminants are extensively degraded in the rumen. The degree of degradation of protein is determined mainly by the physical and chemical properties of the protein in the feed, though the rumen environment and the retention time of the feed in the rumen (Madsen and Hvelplund, 1994) result in variability in the extent of degradation.

There are two aspects of protein degradability that are important:

First is the rate of degradation which affects the rate of production of NH_3 . This may be too slow, optimal or too fast for effective provision and efficient utilization of NH_3 for microbial growth.

Second is the extent of degradation which is a function of rate and time of protein retention in the rumen. This may result in slow steady release of NH_3 over a longer term and/or affect the total amount and nature of the undegraded component of protein that flows on to the small intestine.

For ruminant feeds, the feed value needs to be described in terms of both the value of the feed for rumen micro-organisms and the value of the microbial products and the unfermented feed as substrates for absorption and metabolism in the ruminant body. The utilization of protein, or the animal's response to protein, varies according to the level of feeding, and the composition of the diet as this affects the balance of nutrients

absorbed and type and physiological state of the animal (Egan et al. 1984, Madsen 1994). Mehrez and Ørskov (1977) adapted a technique which has been used experimentally from the 1950's, involving incubation of samples of feed in synthetic fibre bags immersed in the rumen to provide a rapid and practical biological method for characterizing protein sources by determining rate and extent of degradation of protein. The technique is applicable to any dietary component for which an analytical procedure exists. It measures the disappearance of feed constituents from bags containing the test diet after incubation in the rumen for varying periods. The data has wide application in mathematical models of digestion and metabolism in ruminants (Baldwin 1995). Furthermore the rate of breakdown of fibrous carbohydrates is an important determinant of voluntary intake in ruminants (Balch and Campling 1962). Because the time course of degradation of protein in the rumen influences both the N available for the growth of rumen micro-organisms and total protein supply for the host animal and from data on protein degradation, calculation of microbial and dietary contributions to the total amount of protein digested in the intestine is possible. Of the crude protein (N) not degraded in the rumen, a portion may also resist degradation in the intestines and is termed undegraded, undigestible N. Acid detergent insoluble N provides an estimate on this fraction.

The selection of the feeds used in this experiment was based on our own knowledge of the relative degradability of classes of local and traditional ruminant feeds. From the outcomes of the determination of fibre and protein loss during rumen degradation it was the intention to select from these feeds the best supplements for use in further experiments designed to investigate choices of protein providing supplements for practical use in lamb production, considering cost and effectiveness in supporting high growth rate on medium quality pastures to produce lean lamb of high meat quality. Selection was made only on nylon-bag degradability characteristics and our attempt was in this study to evaluate the intestinal digestibility of the residual escape from ruminal degradation.

4. 2 Material and Methods

4. 2. 1 Animals

Eight mature cross-bred sheep about two years of age, each with a permanent fistula in the rumen (Ørskov et al. 1980) were used. Animals were kept in individual pens and fed *ad libitum* with Lucerne chaff and oaten chaff (1/2 w/w). A week before the nylon bag incubation period, animals were moved to metabolism crates and maintained on the same diet during the experiment.

4. 2. 2 Degradability test (Nylon) bags

Bags were made from a Dacron material [4x10 cm], having an average pore size of 12 μm , were prepared following Ørskov's recommendations (1980):

All were sewn with a double line of stitching and the, bottom corners were rounded to prevent any of the sample being trapped, each was numbered permanently with a water proof "Texta" marker.

4. 2. 3 Feeds

Feeds were chosen from those generally used for supplementing sheep in Victoria or were combinations of supplements compounded for reasons related to estimated rate and extent of protein degradability over the time course of a 96 hour incubation.

They were:

BAR I, newly harvested	BAR II; at least 2 years old
LPN I: lupines; new season harvested	LPN II; at least 2 years old
PEAS I; new season harvested	PEAS II; at least 2 years old
OAT: whole oats, PEAS: peas	BEANS: faba beans
WB: wheat bran	UPSFM: un-protected sunflower meal
PSFM: protected sunflower meal	PSFMWB: 1/2 (W/W) protected sunflower meal and wheat bran mixture
FM: fish meal	FMLM: 1/2 (W/W) fish meal and Lucerne meal mixture
FMWB: 1/2 (W/W) fish meal and wheat bran mixture	LMEAL: Lucerne meal

The feeds or mixtures to be assayed were ground and dried in an forced air oven for 48 hours 50°C.

The composition of the feeds used in the serious of experiments presented in this thesis are shown in Table 4. 1. Reason for inclusion of amino acid composition intention to show the likely differences in essential amino acid balance.

Table 4.1. Feed Composition² of feeds used in this Thesis experiments:

Analysis	Fishmeal	PSFM	Lupin	WBran	Barley	LucerneM	Molasses	FMLM	FMWB	PSFMWB
DM % ¹	91.1	90.5	93.9	88.6	89.3	88.9	88.7	86.88	86.70	86.52
Ash % ¹	30	6.83	3.74	5.5	2.36	9.1		14.64	12.41	5.46
N total % ¹	12.5	6.89	5.19	2.72	1.95	2.9	2.3	5.66	5.55	3.87
Protein % ¹	78.1	43.06	32.4	17.0	12.2	18.1	14.4	35.39	34.70	24.18
Crude Fat % ¹	4.8	11.1	10.5	4.76	2.69	3.04		3.32	4.39	6.28
Crude Fibre % ¹	3.3	19.6	10.4	11.2	6.15	28.7		18.78	7.93	12.82
N-free extract %		28.7	34	60.2	77.3	41.4		25.67	37.32	45.93
ME (MJ/kgDM)	14.5	13.3	12	10.1	13	8.2	19.2	10.39	11.57	11.21
TDN %		50.1		71.9				0.00	44.58	59.61
Lysine g/16gN	7.2	3.51	4.4	3.83	3.33	4.95		5.23	4.53	3.43
Methionine g/16gN	2.7	2.334	0.6	1.6	1.64	1.27		1.60	1.80	1.69
Cystine g/16gN	0.8	1.18		1.73	1.84	0.82		0.75	1.31	1.43
Tryptophan g/16gN	1.3	1.6		1	1.11	1.53		1.34	1.01	1.10
Phenylalanine g/16gN	3.8	4.74	3.5	4.66	4	4.74		4.08	4.03	4.31
Tyrosine g/16gN	2.7	2.922	4.7	2.8	2.7	3.14		2.76	2.55	2.61
Leucine g/16gN	6.9	6.78	7.4	6.38	6.25	7.52		6.73	6.03	5.99
Isoleucine g/16gN	4.7	4.034	4.4	3.33	3.2	4.8		4.39	3.47	3.27
Valine g/16gN	5.3	4.298	4.1	4.46	4.55	5.2		4.81	4.36	4.05
Histidine g/16gN	2.2	2.58	2	2.9	2.26	1.89		1.83	2.46	2.57
Aspartate g/16gN	8.9	7.618	11.5	5.76	5.3	9.86		8.78	6.24	5.86
Serine g/16gN	3.5	3.68	5.3	3.87	3.8	4.2		3.65	3.45	3.50
Glutamate g/16gN	12.9	22.22	25.4	22.66	22	9.91		10.01	17.92	20.72
Proline g/16gN	4	4.56		6.16	8.16	6.24		5.07	5.02	5.19
Glycine g/16gN	5.9	6.564	4	5.55	3.54	4.95		4.84	5.21	5.41
Alanine g/16gN	5.7	4.184	3.2	4.18	3.88	5.24		4.96	4.30	3.85
Arginine g/16gN	5.2	7.876	11.4	6.55	4.75	4.61		4.42	5.62	6.42
Threonine g/16gN	3.9	3.486	3.6	3.07	3.2	4.5		3.96	3.07	2.95
Available Lysine %DM				0.65				0.00	0.40	0.40
Calcium g/kgDM	29.4	6.315	2.2	2.059	0.7	10.7	2.4	15.57	10.22	3.29
Phosphorus g/kgDM	23.5	10.53	4.2	12.1	3.4	2.7	6.6	9.05	14.88	10.99
Magnesium g/kgDM	2.9	5.205		9.02	1.1	2.73	3.9	2.76	6.66	7.35
Sodium g/kgDM	12.7	0.245	0.2	0.233	0.37	1.8	0.3	4.94	3.97	0.23
Potassium g/kgDM	10.2	13.38		13.55	4.24	21.34		16.29	11.46	12.42
Iron mg/kgDM	320	332.5		148.8	101.7	407.7		348.77	188.26	192.01
Copper mg/kgDM	6.6	47.36	5.62	15.276	5.9	10.1		8.24	11.45	23.68
Manganese mg/kgDM	6.9	54.04	443.4	170.375	23.5	66.74		43.45	107.70	121.84
Zinc mg/kgDM	66.7	115.3	29.1	70.29	34.6	23.3		34.46	63.59	78.17
Lead mg/kgDM				0.3	0.6	0.78		0.48	0.19	0.19
Cadmium mg/kgDM				0.1	0.1	5.18		3.21	0.06	0.06

¹ Values are determined by direct analysis in the Feed Laboratory of the Faculty of Agriculture and Forestry, The University of Melbourne.

² Values were collected from different resources and rations were calculated.

AFIC-CSIRO (1987).

DeBoer and Bickel (1988).

Jarrige (1989).

McDonald et al. (1991).

4. 2. 4 Experimental procedure

The Dacron bags were washed repeatedly and dried to remove any soluble contaminants. A glass marble was placed in each bag and these were oven dried for 48 hours at 50°C and then weighed for the tare value. Approximately 2 grams of test feed sample was weighed accurately into each bag. Dry matter was determined by drying separate samples for 48 hours at 50°C. Every feed sample was prepared as five time sets (times to exposure to ruminal fermentation), each with three replicates. A “wash” sample was used to determine by repeated washing, the water soluble contents of samples expected to disappear within the first hour of rumen incubation. After each bag was tied separately with a nylon string, samples were replaced in the rumen for 8, 24, 48, and 96 hours. The free length of the string holding the bags in the rumen was fastened outside the rumen canula and was at least 22 cm long to allow the bags to sink into the ventral sac of rumen. This also helped to reduce difficulties with entangling of the bags. At the end of each incubation period, the bags were removed from the rumen and washed thoroughly under running tap water until the rinsing water was colourless. They were then kept frozen until the end of the experiment in plastic bags, when all samples were thawed and washed again in a washing machine with cold water (2*10 min) until all ruminal colour disappeared. They were then oven dried to constant weight at 50 degrees for 48 hours. The proportion of dry matter which had disappeared was calculated from the amount incubated and that left in the bag after incubation.

For the selected feeds as described in the introduction, a further set of analysis were conducted to determine N and NDF contents as medium or slowly insoluble components of the feeds.

4. 2. 5 Analytical procedures of feed samples

All feed samples were analyzed in the Feed Laboratory of the Faculty of Agriculture and Forestry, The University of Melbourne.

The dry Matter, Crude Ash, Total Nitrogen (Crude Protein= $N \times 6.25$), Crude Fat, Crude Fibre contents of feed samples were measured by the Methods recommended by A.O.A.C. (1980). NDF contents of samples was determined with Goering and Van Soest's method (1970).

4. 2. 6 Statistical analysis

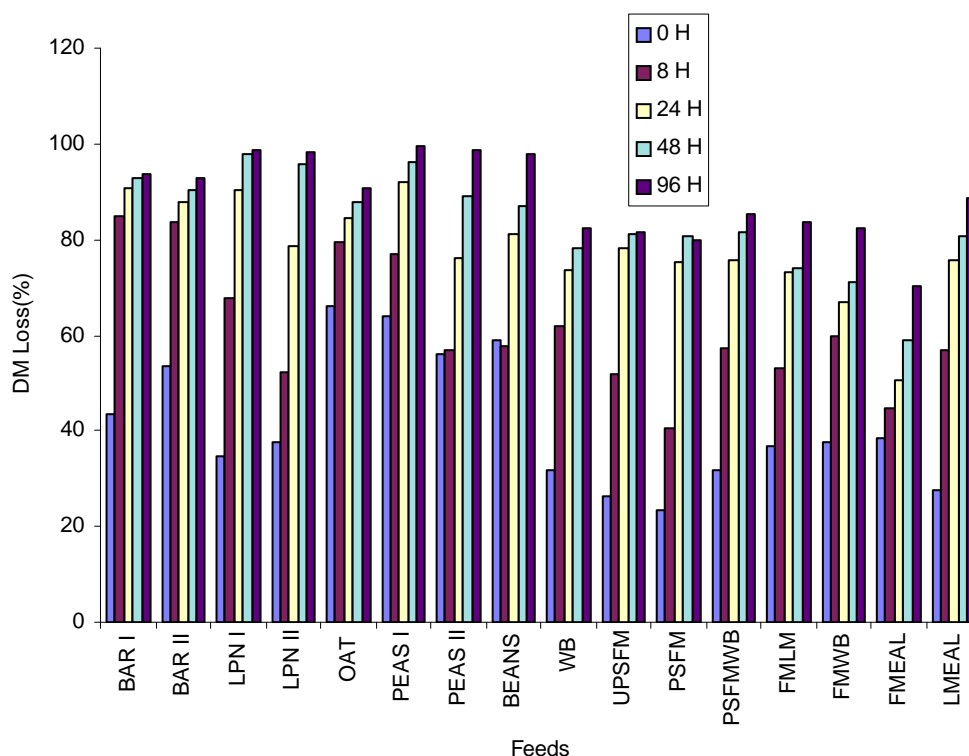
Statistical analyses of dry matter, protein and NDF residues in the nylon bags through the time course of the experiment were analyzed in a two way ANOVA Minitab statistical program, with time, feed material and the interaction of time-feed material as variables. Rates calculated for the fast and slower components of degradation were analyzed by Minitab program in a one way ANOVA..

4. 3 Results

4. 3.1 Dry matter loss

Dry matter loss percentage of feeds after 0 (soaked and washed with water), 8, 24, 48 and 96 hours of rumen incubation are represented in Figure 4. 1.

Figure 4. 1. Dry matter loss of different feeds in intervals over 96 hours incubation, ranked in descending order for loss in first 8 hours.



Sample dry matter loss against time the differences being highly significant and differed markedly between the feed samples ($P < 0.0001$) (Figure 4. 1).

Table 4. 2. Dry matter remaining, NDF and protein content of feed residues after 24 hours rumen incubation.

	BAR	FMLM	FM/WB	LPN	PSFM	PSFMWB	UPSFM	WBRAN	FMEAL	LMEAL	SDev	P
DM %	9.2	26.7	33	9.6	24.9	24.2	21.7	26.5	38.1	24.2	0.701	***
NDF %	83.9	75.3	72	100	77.4	82.6	82.4	86.4	0	81.2	1.056	***
P %	1.07	13.77	21.47	0	10.23	4.8	6.633	3.467	51.27	3.233	0.434	***

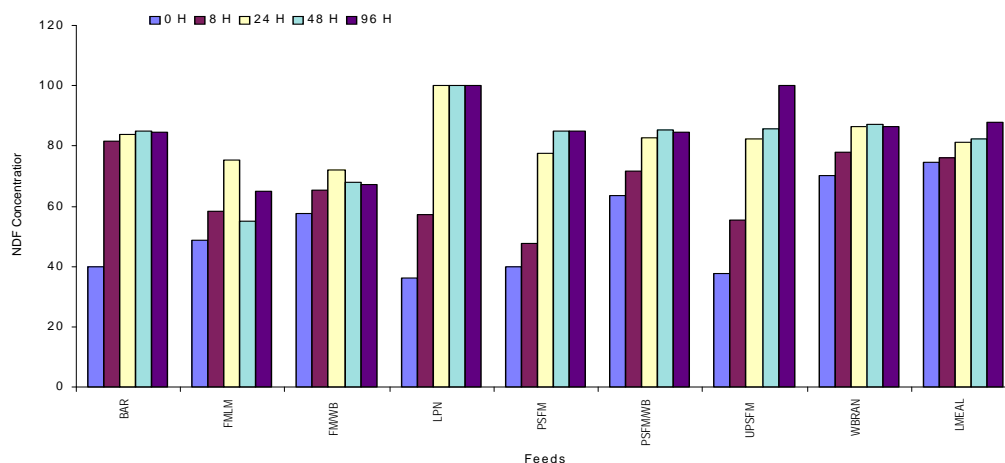
In terms of dry matter loss at the end of 24 hours oats, beans, peas, barley and lupin were found to be the most degradable compared to the other feeds. Although wheat bran and Lucerne meal were included as plant materials with no chemical treatment to provide protection from ruminal degradation, they were considerably less degradable than the others in that class. Unprotected sunflower meal was also found to be relatively resistant to rumen

degradation. Fish meal combinations with both Lucerne meal and wheat bran were found to be the least degradable in rumen after 24 hours of incubation.

4.3.2 NDF content

The relative degradability of cell wall constituents (NDF) in the dry matter is shown in Figure 4. 2.

Figure 4. 2. NDF concentration (% on DM basis) in the residual dry matter of samples after incubation for various periods.



As NDF is a measure of insoluble fibre in feed and faeces which includes cellulose, hemi-cellulose and lignin as the major components present in plant material, it was not measured in fish meal.

In all cases components other than NDF were removed fastest; but FMLM and FMWB show a pattern of residue other than NDF that was digested at rate similar to that of NDF. FMLM appears to have a bi-model degradation pattern in that a component other than NDF is removed rapidly at first then leaves a relatively resistant non-NDF fraction.

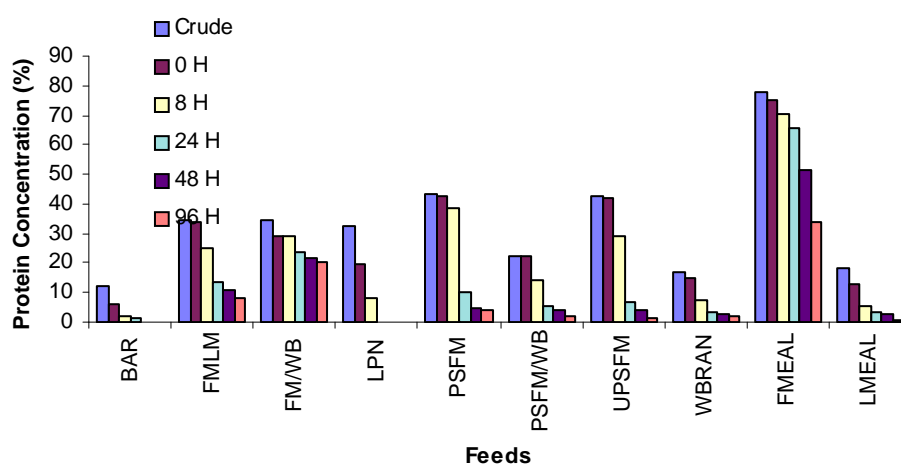
After 24 hours incubation only the NDF fraction was left from LPN. The NDF in the un-degraded fraction in the nylon bag at that period were respectively WB 84.4%, BAR 83.9%, PSFM/WB 82.6, UPSFM 82.4%, LMEAL 81.2%, PSFM 77.4%, FMLM

75.3% and FMWB 72.5 % of DM residue. UPSFM was only supplement in which NDF component increased as proportion of residue after 48 hours.

4. 3. 3 Protein contents

Protein content of the residue after varying periods of incubation are represented in Figure 4. 3.

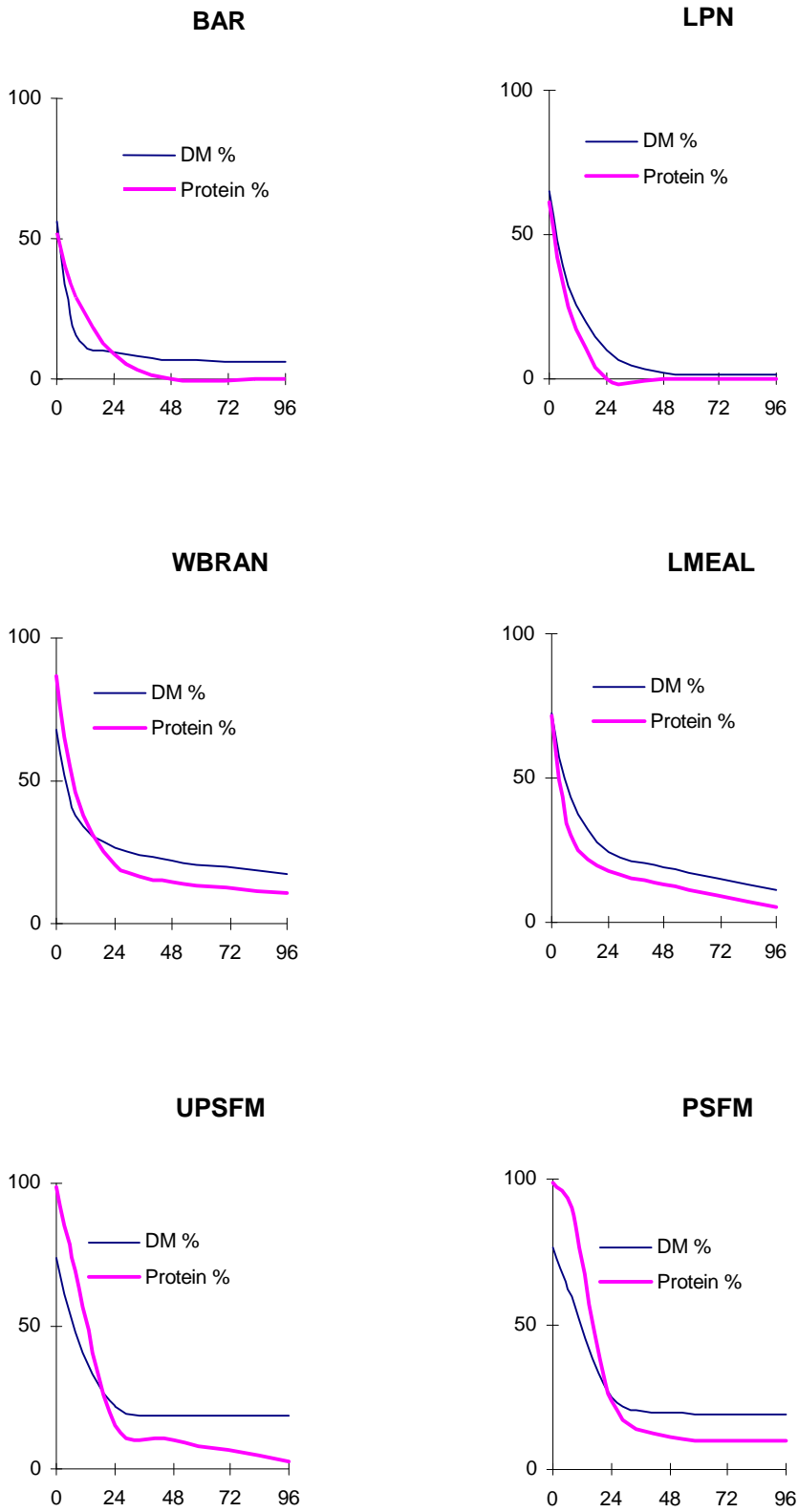
Figure 4. 3. Protein concentration in the residual dry matter after incubation of various periods (crude protein = without incubation as percentage; 0, 8, 24, 48, 96 hours incubation).

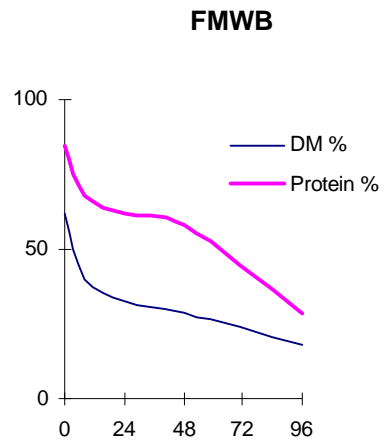
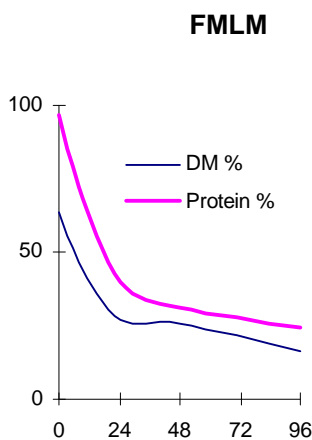
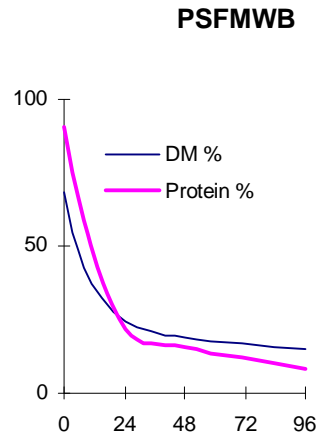
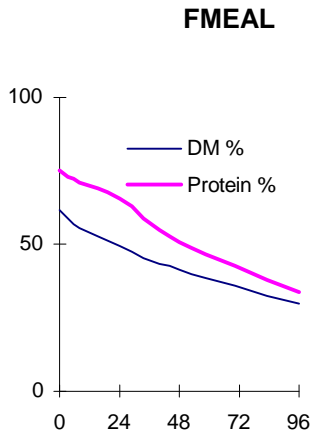


In all cases, the protein component is removed more rapidly than other DM constituents. The fishmeal was highest in protein content and was the least degraded in the rumen. LPN had a higher protein content which had almost disappeared at the end of 24 hours. The protein of WBRAN was found to be less degradable than that of LMEAL, even though they contained similar amounts of N.

A detailed comparison of proportional rates of DM loss and protein degradability is shown in diagrams in Figure 4. 4.

Figure 4. 4. Fitted curves for dry matter and protein remaining as percentage of DM (% remaining) and protein (as % of protein at start).





Both BAR and LPN dry matter and proteins were highly degraded in the rumen. The remaining DM in BAR was mainly an NDF residue (Figure 4. 2). WBRAN protein was degraded more slowly than LMEAL protein. WBRAN degradability was found as resistant as PSFM protein in terms of percentage protein degradation.

Formaldehyde treatment protected PSFM protein especially during the first 8 hours and UPSFM protein was degraded more rapidly than PSFM. FMEAL was found to be both highly resistant to rumen degradability and a good source of NH₃ released in rumen. PSFMWB was a reasonably good source of RUP. FMLM protein was degraded more rapidly than FMWB's during the first 48 hours.

4.4 Discussion

All feed samples are extensively degraded in rumen over the period of incubation. Degradability of LPN and BAR were the highest, and the residue was NDF. UPSFM lost 80 % of its contents and the residue was comprised mainly of NDF. LMEAL figured a similar situation with UPSFM. WBRAN lost 75% of DM and the residue was mostly NDF. FM was slowly and steadily degraded throughout. FM mixed with LMEAL and with WBRAN both reflect this as but there is an imposed 2nd characteristic arising from the other part of the mixture, particularly in NDF content.

Contamination of the residue in the nylon bag with microbial material can result in an underestimation of degradability. Thus Mathers and Aitchison (1981) indicated from isotope tracer studies with ³⁵S that up to 18% of bag residue N consisted of microbial N. The effect on estimates of protein degradability / degradation rate is less for concentrated protein sources than for fibrous forage materials. While this aspect has been considered further by Dixon and Chanchai (2000) no attempt was made in this study to correct for microbial contamination of bag residues. The methods used to derive corrections were not presented in this project. The degradation rate, therefore remains underestimated by values which could be as high as 3 – 4 %.

Considering the circumstances in rumen such as wetting, (particularly if the samples are oven dried) and time for colonization, less than 24 hours of incubation may not be an ideal for degradability calculations.

Across all samples the higher the DM degradability, the higher the relative rate of protein degradation, the exceptions being two feeds which can be described as high in RUP content. One is FMEAL which is a high biological value, animal originated protein, and the other is PSFM which was treated with formaldehyde to protect against rumen micro-organisms. WBRAN performed more like FMEAL and PSFM, than like the other plant protein supplements, possibly because of the heat generated during pelleting (Lorenz and Kulp 1991).

When FMEAL alone was placed in the nylon bag and washed, up to 25% was removed in this process, indicating either the presence of a readily soluble protein, or

the presence of very fine material lost through the Dacron material's pores. Such fine material is not rapidly degraded and would enter the more rapidly removed "fluid" fraction of rumen content. When combined with plant material like Lucerne as in experiment 1 and 2 (Chapter 2-3) and pelleted, this altered the behavior of the FMEAL.

The fishmeal fraction of both FMWB and FMLM combinations showed little immediate loss on washing process and had a higher ruminal degradation resistance especially for the FMWB; so that at the end of 24 hours more than half of the protein was still undegraded.

The heat that occurred during the pelleting process may have contributed an extra effect on protein degradability of FMEAL, such that FMEAL in both WBRAN and LMEAL mixes performed with higher RUP value during the long incubation period (Figure 4. 4).

The absolute amount of FMEAL protein degraded per 100 g was (34.36 g) during 24 hours rumen incubation indicating a relatively consistent degradation rate with an average rate of 1.5 g/hour/100g protein.

Protected and unprotected sunflower meal samples were resistant to the washing procedure, and dry matter loss rates were nearly the same. However, the formaldehyde treatment of PSFM appeared to reduce the degradability of protein relative to that of other DM constituents, especially in the 8-hour incubation period. The significant difference in NDF content between formaldehyde treated PSFM and un-treated UPSFM at the end of 96 hours may be as a result of increased protection of non-cell wall constituents or lack of local N sources to support microbial fermentation of fibre in UPSFM.

With WBRAN, dry matter and protein degradabilities were more persistent than with the other feedstuffs except FMEAL. With the PSFMWB combination the protein fraction was dissolved more quicker than for PSFM itself possibly due to WBRAN's aleurone cells content which may support rumen organisms and favour more rapid colonization. This aspect warrants further investigation.

The metabolisable protein calculations of feeds according to AFRC's (1993) recent released equations (1-2) (Section 1. 6. 2) are represented in Table 4. 2.

Table 4. 3. The metabolisable protein values of feeds calculated with AFRC (1993) equations.

Feeds	CP	DUP	DMTP*	MP**
BAR	12.20	1.07	7.78	8.84
FMLM	35.40	13.77	22.57	36.33
FMWB	34.70	21.47	22.12	43.59
LPN	32.40	0.00	20.66	20.66
PSFM	43.06	10.23	27.45	37.68
PSFMWB	24.20	4.80	15.43	20.23
UPSFM	43.06	6.63	27.45	34.08
WBRN	17.00	3.47	10.84	14.30
LMEAL	18.10	3.23	11.54	14.77
FMEAL	78.10	51.27	49.79	101.06

Abbreviations: CP; Crude Protein; DUP; Digestible Un-degraded feed Protein DMTP; Digestible Microbial True Protein, MP; Metabolisable Protein

DMTP* (g/d) = 0.75*0.85*MCP = 0.6375MCP(g/d) (Equation 1)

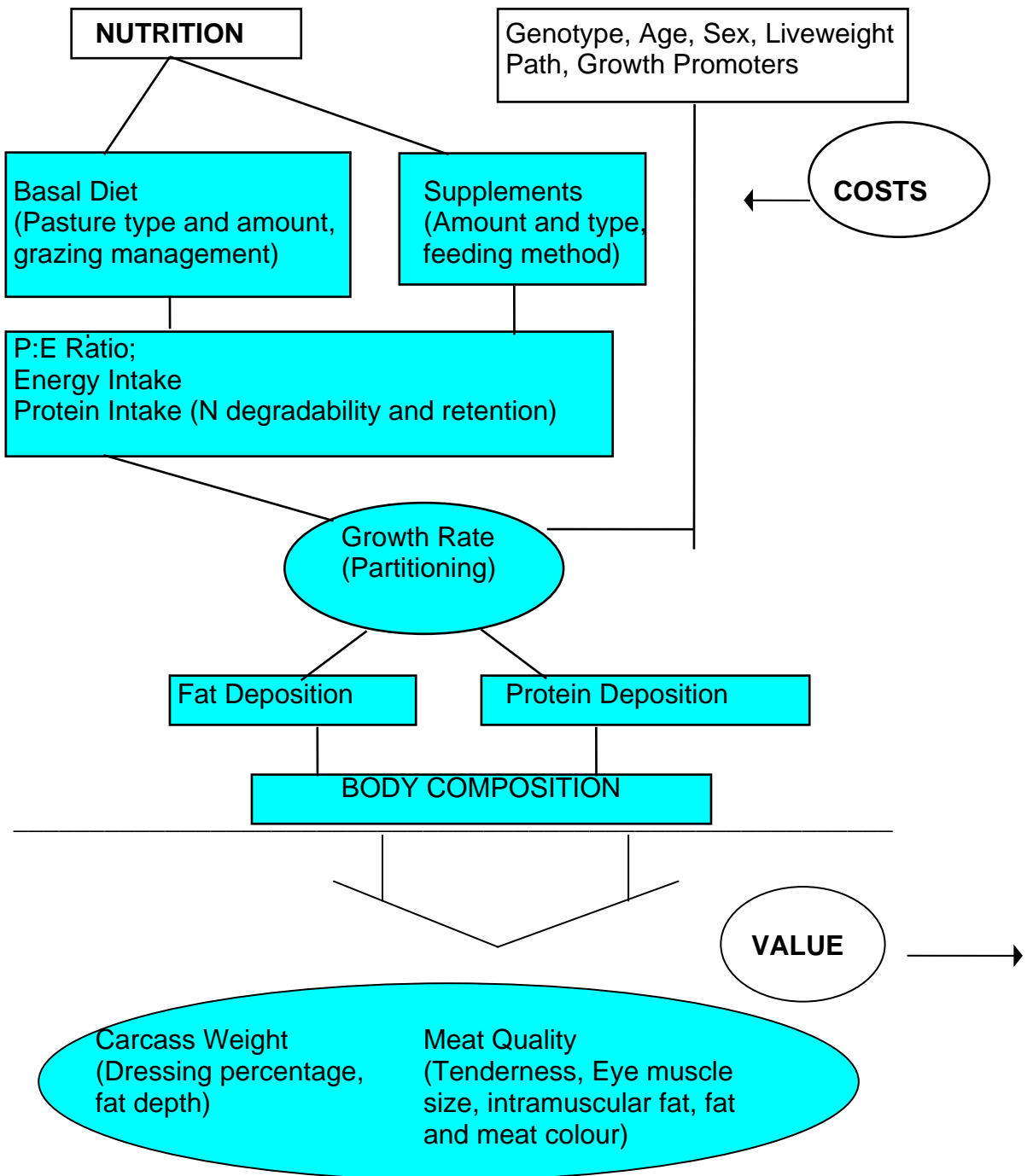
MP** (g/d) = 0.6375MCP+DUP (AFRC, 1992). (Equation 2).

Especially with the FMEAL itself and its mixes such as FMLM and FMWB, the MP values were higher than the CP values. These 3 results of calculation might simply reflect the problems of application of the standard formula. For simplicity the feed used in the experiments of this thesis were considered in terms of its DCP (digestible crude protein) ratio and its ME. Nonetheless FMEAL and its mixtures clearly provide better supplies of RUP or RDP (particularly Slowly Degraded Protein (SDP; AFRC 1993) or both, than the others.

As a conclusion; BAR is a very poor source of protein supplement with low content of RUP, that can be considered as an energy source for animals. Lupines are a good source of protein which is highly rumen degradable and could be a good source of NH₃ for rumen fermentation though the release is rapid with more than 60% gone in the first 8 hours.. Protected and unprotected SFM are both good sources of protein and the balance of RUP and RDP of UPSFM is ideal for the ruminants. However, we must consider its cost and competitive use in feeding other (simple stomached) animals such as pigs and poultry. LMEAL is a widely used source of protein for ruminants but provides mainly RDP up to 24 hours and thereafter most protein was disappeared. Its cost and availability may be a limiting factor for using as a ruminant feed. WBRAN showed a excellent performance in rumen degradation, but with low protein concentration and high fibre, may play a strategic role where fibre does not result in lower intake. Likely benefits of FMEAL are due to both RUP and RDP

fractions, steadily, limited degradability can support the most efficient microbial growth and then whatever remains undegraded from rumen micro-organisms flows on, to be digested in the small intestines.

Per unit of metabolisable protein, PSFM, FMWB FMLM may be cheaper, but the value per \$ invested in supplement depends on performance of flock animals provided with the supplement under grazing conditions. Feeds containing high metabolisable protein in both RUP and RDP forms such as lupines, wheat bran, protected sunflower meal and fishmeal were examined in the further experiments repeated in Chapters 5 and 6 of this thesis to evaluate, the usefulness for large and lean lamb production.



Chapter 5 and 6 are focused on the use of different protein sources in supplementing young sheep and their affects on carcass gain and composition.

Chapter Five: An alternative high protein ration to grazing young sheep.

5.1 Introduction

The autumn born lambs which are newly weaned may need some extra supplementary feeding during grazing in short and rainy winter days for both the reasons of need under severe weather conditions and of availability with limited amount of green material in pasture. Grazing animals select green herbage in preference to dead material and leaf in preference to stem material (Nicol 1987). Pasture composition can have considerable effect on lamb liveweight gain(Rattray et al 1979, 1982) and liveweight gain increases with clover content (Nicol 1987, Harris 1987). Animals may show a great response to supplements under these conditions. Thus we observed in experiments described in Chapter 2 and 3 that supplementary feeds, particularly those of high P:E ratio, may improve the liveweight gain, growth rate and carcass leanness of young sheep. Fish meal was effective in supporting better LWG in low LW animals particularly. However, fish meal is expensive can be wasted in feeding and not well accepted unless incorporated with a mixture. Thus there is a need to dilute or find less costly but effective alternatives. The hypothesis of the experiment to be described here was, that supplementing the animals with materials of different protein content and degradability would result in significant differences in growth rate and fat deposition of animals.

Expensive feeds like fishmeal or meat meal with high biological value protein content can be used as supplementary feedstuffs for ruminant animals. Fish meal is a supplement which is expensive, and is a limited resource with multiple uses as well (De Boer and Bickel 1988). Since fish meal is also a good source of protein for simple stomached animals, which have usually better feed conversion rates than ruminants (broiler chickens 2.22 kg feed / kg liveweight or fish or pigs) this affects its cost. The use of fish meal as a ruminant supplementary feedstuff becomes uneconomic unless the amount used is small and the result is a much more valuable

product. Meat meal on the other hand appears to be more variable in composition and biological value (Atkinson and Carpenter 1970). Meat meal has also been under a cloud of concern because of the linkage to bone spongyform encephalitis (Mad Cow Disease). Blood meal is both variable in terms of effects of processing and of lower biologic value because of an intrinsic deficiency in isoleucine (Fisher 1968).

As the basic rule for a supplementary feeding is “best supplement is the least cost supplement as long as it works” (Hinton 1994), some other less expensive products or by-products may be alternatives for this purpose.

Sunflower meal is a by-product of the food oil industry that is used as a protein supplement for farm animals. The characteristics of SFM relating to rumen degradability of protein and NDF were described in Chapter 4, it appears to be a good supplementary feed at reasonable cost. The treatment of sunflower meal with formaldehyde protects its protein from rumen degradation and increases the supply of amino acids to the small intestine (Chalupa 1975, Hamilton 1992 et al., Ashes et al. 1993).

Wheat bran is a reasonably cheap and highly palatable feedstuff useful for ruminants, and has been used primarily as an energy supplement. However, it has a considerable protein content (17.0 %) comparing to its energy (10.1 MJ/kgDM). The energy and protein contained in wheat bran are diluted with fibre and utilized better by ruminants than by mono-gastric animals, because the “laxative effect” does not cause problems (Kent and Evers 1994). Wheat bran as a feedstuff in pelleted forms increases the nutritive value by modifying the rumen degradability of protein because of heat which occurs during the pelleting process (Lorenz and Kulp 1991). These characteristics were investigated in Chapter 4.

Leguminous seeds, especially lupines are commonly regarded as protein concentrates because of their high protein and energy content (Table 4. 1). Lupines appears to have advantages as a ruminant feedstuff in that it contains little starch, though other readily fermentable oligo sacharides are present (Jarrige 1989, Rowe et al. 1989). It is palatable and it has a high ME value and digestibility (Murray 1992). As a supplement to poor quality roughage, lupin seed can have a significant positive effects on energy intake and the digestibility of both the dietary N and fibre components of

the base roughage (Margan 1994). The characteristics of degradation in the rumen of both protein and DM including NDF were investigated in Chapter 4.

In this experiment, feeds described in Chapter 4 (lupines, fishmeal / wheat bran mix. and protected sunflower meal / wheat bran mix.) were examined for effectiveness as supplements to pastures in early winter, for young animals having high P:E ratio requirements. The scenario was one of a series focusing on growing weaned lambs to target weights for the lean lamb market, considering the seasonal changes in pasture conditions throughout the year. The major yield parameters were liveweight gain, condition score, carcass weight and carcass fatness. Wool growth (fleece length) was measured as monitoring other effects of supply of protein supplements (Leng et al. 1984).

5.2 Material and methods

5.2.1 Experimental conditions

The experiment (Experiment 4) was conducted at the Pastoral and Veterinary Institute, Hamilton (known as Wool Capital of World) in Western Victoria (142° East, 37.5° South). Experiment time was selected as late autumn when autumn lambs would be available and achieve the best market value in winter. The experiment ran from May (after a preliminary period of 2 weeks) through the end of June 1995, and was designed to determine the effects of supplementation and grazing under the current pasture conditions on rate of growth of weaned lambs, carcass weight and fat content.

The weather conditions, temperature, rainfall, sunlight and wind data were supplied from the local meteorology services.

5.2.2 Pasture measurements

Animals were placed in paddocks of 1.55 hectares of improved pasture. The botanical composition being a combination of annual grass and legume varieties, dominantly legumes. Pasture botany, quality and abundance were measured in three week intervals by methods recommended by Department of Agriculture, Victoria (Cayley and Bird 1993), as described in Chapter 2.

Results of measurements describing pasture conditions are given in Table 5. 2 below.

5. 2. 3 Animals and treatments

Eighty crossbred Jonesdale* male (cryptorchid), newly weaned, 16 weeks of age lambs were allocated by stratified randomization to 4 treatments each with 20 lambs, approximately 31-32 kg LW at the commencement. All animals were drenched for the control of helminthes and allowed to graze in a paddock rotational system (rotated in every 3 weeks) at a stocking rate of 77.5 m²/head/day (pasture allowance). The pasture mass available in the paddocks are presented in Table 5. 2 below. The four treatment groups were:

1. Nil - grazing pasture only.
2. Lupin - supplemented as a group (P/E= 32.4/12) 350 g/head/day. LPN with a 24 hours DM degradability of 90 %, estimated Metabolizable Protein 20.66 %(Chapter 4).
3. Fish meal/wheat bran pellets(P/E= 34.7/11.6) 350 g/head/day. FMWB with a 24 hours DM degradability of 67 %, estimated Metabolizable Protein 43.6 %(Chapter 4).
4. Formaldehyde treated sunflower meal/wheat bran pellets (P/E= 24.2/11.2) 350 g/head/day. PSFMWB with a 24 hours DM degradability of 75 %, estimated Metabolizable Protein 20.23 %(Chapter 4).

Animals were introduced to feeds for two weeks during the preliminary period and fed twice a week in intervals of 3 and 4 days at the same time in the morning. The

* Jonesdales are a synthetic terminal sire line developed from the foundation breeds of Dorset, Suffolk and Hampshire with smaller infusions of Merino and Border Leicester, with the breeding goals of rapid growth to 50 kg LW, lean, well muscled carcass, highly fertile, polled and resistant to worms.

control group was supplemented with the same level mineral combination with a commercial block mineral licks.

5. 2. 4 Preparation of supplementary feeds

Lupin (*Lupines angustifolius*) was supplied from a commercial feedstuff dealer and fed as the whole grain.

The other supplements, being mixtures of all loose feed, were pelleted for a better distribution of nutrients and convenience of feeding, considering likely winter weather conditions of wind and rain,. Fish meal (30 %), wheat-bran (62%) in loose form were mixed with a mineral mixture (Table 5. 1) (3%) and molasses (5%) and water (10%) and then mixed in a horizontal mixer until the combination became homogeneous and moist enough to stick together. After the pelleting process, pellets were baked in an aspirating oven for 48 hours in 50°C.

For the sunflower meal-wheat-bran combination, 30% sunflower meal, 62% wheat-bran, 3% mineral mixture and 5% molasses were mixed, pelleted and dried as the same procedure for fish meal/wheat-bran pellets above.

The chemical composition of diets is presented in Table 4. 1.

Table 5. 1. Mineral Mixture added to experiment feeds:

Minerals	Amount (g/100g)
NaCl	27.0
Na ₂ SO ₄	20.0
KCl	10.8
CaCO ₃	8.0
Ca ₂ HPO ₄	27.0
MgSO ₄ .7H ₂ O	6.8
Trace minerals	0.4
Trace Minerals*	(g)
CoSO ₄ .7H ₂ O	0.67
CuSO ₄ .5H ₂ O	1.35
FeSO ₄ .7H ₂ O	33.70
ZnCO ₃ .2ZnO.3H ₂ O	5.73
MnSO ₄ .4H ₂ O	6.75
KI	0.34
Na ₂ SeO ₄	0.17
K ₂ MoO ₄	0.50

*The trace minerals are formulated on g basis, mixed previously and than added to mineral mixture.

5. 2. 5 Fleece Length Measurement

Fleece length of animals was measured by a ruler in millimeters on the shoulder of animal in every monitoring period as described by Leng et al. (1984).

5. 2. 6 Liveweight, condition score and fat depth

Animals were weighed and condition scored at two and three week intervals by the same operator on the same scales at the selection time before feeding supplements as described previously in Chapter 2.

When animals reached an average liveweight 42-43 kg at the end of 7 weeks and meat market has reached the best value of the season, all lambs were slaughtered in a commercial slaughter house in Hamilton, hot carcass and fat depth were measured by procedures reported in Chapter 2.

5. 2. 7 Statistical analysis

Statistical analysis were made with Minitab in analysis of variance, one way ANOVA with LW as a covariate and 2 way ANOVA with treatments and subgroups or LW.

5. 3 Results and Discussion

5. 3. 1 Weather conditions

Weather conditions were recorded by the Meteorological Station on the property. The daily rain fall and sunlight during the experiment were presented in Figure 5. 1. The temperatures are presented in Figure 5. 2.

Figure 5. 1. Daily rainfall (mm) and sunlight (h) during the experiment.

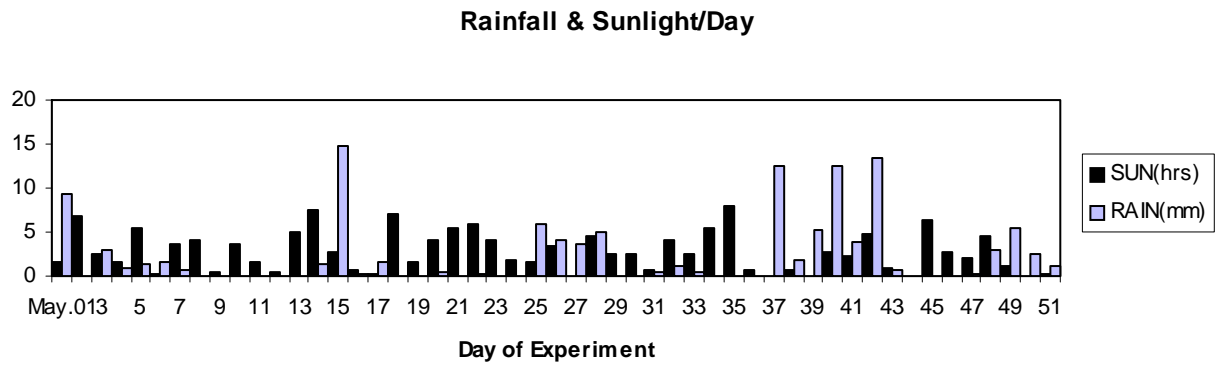
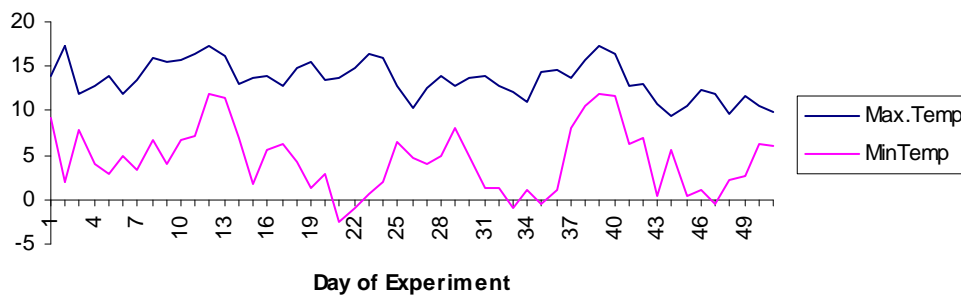


Figure 5. 2. Minimum and maximum temperatures (°C) during the experiment.



5. 3. 2 Pasture conditions

As summarized in Table 5. 2, both pasture green content and legumes as a proportion of the green content increased throughout the experiment. Pasture growth was adequate to support LW gain throughout, as a result of rainfall and sunlight even though the season was winter. At the beginning of the experiment there was 2.8 kg DM/Ha of green pasture available (paddock 4 = the poorest) per sheep in dry matter basis and then increased to 25.3 kg by the end of the experiment (June 21). Legumes (mainly clovers) increased from 45 to 60% through the experimental period. As discussed in the review of literature, sheep prefer to graze green material rather than

dead, and legumes rather than grass. There was always a sufficient base diet for maintenance. Live weight gains of animals recorded were supporting this idea.

Table 5. 2. Pasture rotation and conditions observed during the experiment.

	15-May-	5-Jun-	21-Jun-			
Paddock Rotation						
Pd1	Lupin	PSFM/WB	Control			
Pd2	FM/WB	Lupin	PSFM/WB			
Pd3	Control	FM/WB	Lupin			
Pd4	PSFM/WB	Control	FM/WB			
	2-May	15-May-	5-Jun-	21-Jun-	Mean	Difference
Green Content (%)						
Pd 1	82.1	95.3	99.7	100	94.3	17.9
Pd2	76.8	93.9	93.8	100	91.1	23.2
Pd3	81.4	91.1	99.4	100	93.0	18.6
Pd4	77.4	93.2	99.2	100	92.5	22.6
Legume Content(%)						
Pd 1	49.7	55.8	72.4	62.6	60.1	12.9
Pd2	36.8	44.1	41.5	45.3	41.9	8.5
Pd3	52.1	68	79.2	52.3	62.9	0.2
Pd4	43.2	51.7	75.8	43.2	53.5	0
Pasture Mass (kgDM/ha)						
Pd 1	260	220	516	878	468	678
Pd2	92	203	268	424	247	332
Pd3	110	123	78	191	126	81
Pd4	72	64	209	506	213	433
Green Mass (kgDM/ha)						
Pd 1	213	210	514	878	454	664
Pd2	71	191	251	424	234	354
Pd3	90	112	77	191	118	102
Pd4	56	60	207	506	207	450

5. 3. 3 Animal performance and carcass conditions

Paddock rotation did not effect the animal performance of liveweight gain.

All treatment groups grew at similar rates during the period of the experiment and valued well in the market. At the end of the experiment daily LWG and dressing percentage differences of the animals were statistically significant for all treatment groups compared with the Control. Final weight was not significantly different among supplements. Condition score, wool length growth and carcass fat depth were not significantly different between the animals (Table 5. 3).

Table 5. 3. Liveweights, LW gain, condition score, wool length growth, carcass yield and fat depths of animals in each of 4 treatment groups.

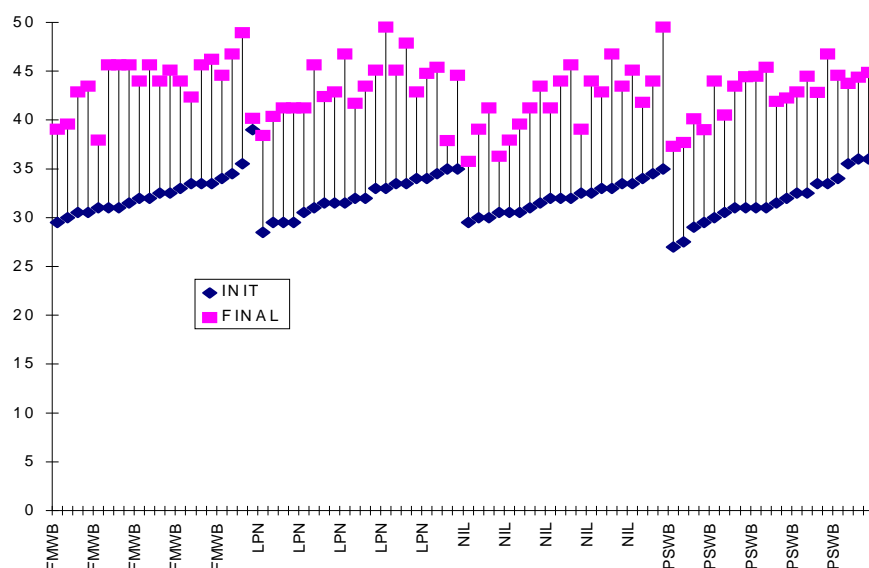
	CONT	LPN	PSFM/WB	FMWB	Sem ²	P
Starting LW ¹ (kg)		32.1	32.1	31.7	32.5	3.27
NS						
Final LW (kg)	42.1	43.4	42.8	43.9	5.15	NS
ADG (g/day/head)	204	230	226	232	2.68	*
CW (kg)	19.2	20.0	19.1	20.3	2.21	NS
C/S	2.4	2.5	2.4	2.4	2.39	NS
Wool Length(mm)	56.6	59.3	59.6	57.3	3.72	NS
Drsn %	45.7	46.1	44.6	46.3	3.11	*
Fat depth (mm)	13.4	16.1	13.4	14.1	2.49	NS

¹Starting LW as covariate, ²Sem; Pooled Sem

All supplemented animals especially the FMWB ones ended up with higher liveweight flocks in final weights (Figure 5. 3).

Statistical analysis of data relating to groups of animals with widely differing initial liveweight as is found in a commercial flock (Table 5. 3) has been based on covariate analysis with initial liveweight as a covariate. Analysis of Initial LW showed no significant differences between dietary treatment groups but high SE values within all diet groups. On this basis final liveweight was shown in this experiment not to be significantly different between dietary treatments. FMWB and Lupin fed groups were heavier than the pasture only (NIL) group at the conclusion of the experiment with an increase in the SE value, while PSFMWB group was intermediate in mean final liveweight and did not differ significantly from any other group.

Figure 5. 3. Starting and final liveweight spread of animals.



At the outset of the experiment two liveweight subgroups (Heavy v Light) within each dietary treatment group were identified in the stratified randomization of animals to diet groups. The data on liveweight and liveweight gain and fat depth were subjected to analysis of variance in a 2-way ANOVA (diet x liveweight subgroup). Analysis on this basis (Table 5.4) revealed a significant difference in initial liveweight ($P<0.01$) between Heavy and Light subgroups and a significantly greater final liveweight ($P<0.05$) and liveweight gain ($P<0.05$) for FMWB- and Lupin- fed animals, particularly for the Light subgroup. Over both liveweight subgroups, FMWB animals performed best but , for the Heavy subgroups, the Lupin –fed group was the only group to show a significant better LW gain than the NIL group. The Light subgroup fed PSWB showed the lowest rate of liveweight gain of all groups, though not significantly different from the LW gain of the Light-Control group; for both of these Light x Diet groups, LW gains were significantly lower than the Light –FMWB group.

Though among the Light subgroups, FMWB animals had significantly greater GR fat depth than NIL dietary treatment (Table 5. 4). Among the Heavy subgroups, the NIL group, though significantly lighter, had greater GR fat depth than the FMWB fed animals. The interactions indicated in these results raises major questions relating to growth rate, carcass composition and market

specifications that can be met by different liveweight classes of lamb fed the same supplement. Over the four different nutritional treatments, faster growth rate of light lambs, associated with feeding of supplements (particularly FMWB) led to heavier carcass and greater GR fat depth. In contrast in heavier animals faster growth rate principally achieved with both LPN and FMWB, was associated with lower fat depth. If found in flock feeding systems such effects may call for separate feeding strategies for animals of different liveweight class.

Table 5. 4. Liveweight and carcass fat depth of animals in light (< median) and heavy (> median) subgroups.

Variable	CONTROL		LPN		PSWB		FMWB		SEM ¹	P
	Light	Heavy	Light	Heavy	Light	Heavy	Light	Heavy		
IW ² kg	30.9	33.5	30.6	33.9	29.9	33.9	31.0	34.3	1.28	**
FW kg	39.3	44.1	41.0	45.8	37.4	44.7	41.7	46.0	2.67	*
ADG g	171	216	212	243	153	220	218	239	12.6	*
Drs%	51	52	53	53	52	52	51	51	2.8	NS
GR mm	12.1	15.0	14.5	14.8	13.3	13.6	14.7	13.2	1.11	*

¹SEM; Pooled, ²IW as covariate.

This raises the question of independence of the experimental units examined in such a statistical analysis, and the partitioning of variance into the effects identified as those due to diet, those due to initial liveweight, and any interaction between these variables.

The statistical analysis of the eight groups (4 dietary treatments x 2 weight groups) can be considered valid only if the experimental units are independent in the statistical sense. The use of data for individual animals and subgroups of animals rather than the entire group as the experimental unit may therefore be challenged. However, true independence in field experiments is difficult to achieve, particularly if the desired similarity of basic pasture conditions for the animal groups is sought by grazing supplemented animals in common. In this experiment all animals on each dietary treatment grazed and had access to the respective supplement in common and therefore individual animals and perhaps classes of animal (liveweight subgroups) had the opportunity to interact. Animals in different dietary treatments on the other hand were rotated through separate paddocks, had no direct interaction other than through the leader-

follower effects in pasture use; but were however, from time to time subjected to recorded and reported differences in pasture quantity and quality. The allocation of animals to two classes on the basis of initial liveweight also introduces a question of bias since previous history dictated the class into which the animals were allocated. Provided this is known any interpretation based on the statistical analysis can be. Consequently it is pointed out that any effects identified as significantly different between Heavy and Light sub-groups, dietary treatment groups and interactions are interpretable only on the basis that variance due to all animal – animal interactions are partitioned as aggregated into main effects or are represented in residual variability (error). The effects attributed to initial liveweight class may arise through differential growth impetus, positive or negative effects of competition for pasture or supplement affecting all animals in a given liveweight class or affecting more animals individually in a given liveweight range. Any such effects due to behavioral and physiological factors are subject to the constraints imposed in the specific experiment. Competition for pasture will vary with stocking rate and pasture availability. Competition for supplement will depend on factors such as feeding method (trail or trough space) and frequency (e.g. daily or weekly), attractiveness of the supplement and the physical ingestion rate. Such factors were not investigated in the work reported in this thesis. In the next Chapter, issues relating to statistical analysis and experimental design relating to independence of experimental units were addressed under controlled conditions indoors with each animal individually penned.

In order to relate results for diet and liveweight groups to an assemblage of previous field experiments, the model “GrazFeed” was challenged with input data from this experiment and the output data on liveweight gain compared (Table 5.5).

Table. 5. 5. The GrazFeed predictions for the present pasture and animal conditions of the experiment.

Treatment	Predicted Pasture Intake.(kgDM)	Predicted Supp Intake (kgDM)	Predicted LWG (g/day)	Actual Supp Intake (kgDM)	Actual LWG (g/day)
CONTROL	0.76	0	72	0	204
LPN	0.54	0.31	113	0.35	230
FMWB	0.76	0.32	129	0.35	232
PSFMWB	0.76	0.31	126	0.35	226

Animals of both NIL and treatment groups grew up better than GrazFeeds predictions. Although GrazFeed predicted improved LWG due to supplements, the actual LWGs were not greatly enhanced. GrazFeed appears to have underestimated growing animal performance at pasture alone. The stocking rate of the pasture was low sufficiently that pasture provided enough grazing material to animals; that animals' upper limit on daily green pasture intake would have been maximized and animals consumed more amounts of roughage than GrazFeed predicted. In summary, liveweights gained by animals in the experiments were reasonably acceptable considering the seasonal conditions in the region but there was no statistically significant benefit from using the supplements despite the underestimating predictions made by GrazFeed.

In summary actual liveweight gains by animals in this experiment were acceptable considering the seasonal pasture conditions, but in contrast to predictions of GrazFeed, there was no statistically significant benefit in liveweight gain from any supplement, unless initial liveweight was taken into consideration, either by covariance analysis or by examining effects of supplements on groups of animals divided into two classes , heavy or light on the basis of initial LW. The hypothesis deriving from this experiment has been pursued in Experiment 5 (Chapter 6, following).

Chapter Six: Use of different protein sources in supplementing young sheep and their affects on carcass composition.

6.1 Introduction

In the field experiment described in Chapter 5, pasture was assessed available (Hodgson 1990) at approximately 250kg/Ha green mass, 100 % green, and 50 % legume was of good quality and adequate for that number of animals grazing according to the amount predicted by GrazFeed model. There was no paddock rotation effect on rates of LW gains of the groups of animals. Daily liveweight gain and dressing percentage differences between grazing alone (CONT) and the supplement treatments which included LPN, FMWB and PSFMWB were statistically significant ($P < 0.05$). The fat depth (GR) between heavy and light sub-groups were found statistically significant ($P < 0.05$). As has been discussed in the review of literature the results of many studies (Egan and Walker 1975, Ørskov et al. 1976, Preston and Leng 1987) on poor quality feed indicate that the amount and quality of supplementary protein has a great effect on rates of growth and protein deposition by the animal. It can also affect carcass leanness of sheep when comparisons are made between animals of the same age, but these differences are substantially reduced when comparisons are made at the same body weight (Black 1974).

The effects of amount and quality of supplementary feeds on quality of output (carcass protein content and leanness) were found in earlier experiments (Chapters 2, 3) to be related in part to the starting liveweight and possibly the growth rate of the animals when un-supplemented. However, in Experiment 4 (Chapter 5) we were unable to identify any significant advantage in growth rate or carcass leanness that was associated with any specific class of protein supplement. Those may have been a problem with pasture measurement or a real effect that the intake of high quality pasture components. Though all supplements increased growth rate, the effect was marginal. This was not predicted by the model "GrazFeed" which for conditions of Experiment 4, substantially underestimated animal growth rate on pasture alone and overestimated the response to supplements. Protein provision in supplements for

young lighter liveweight group of weaned sheep on medium to high quality pasture did however, resulted in higher LW gain and lower fat contents in 1st and 2nd experiments.

In this experiment I have examined the responses in growth and carcass composition of young weaned sheep offered a good quality base diet in controlled indoor conditions. The digestibility of the feed, the live weight gains and carcass characteristics, partitioning of the body components such as internal organs or digestive tract have been measured and, the responses to protein supplements has been examined for supplements calculated to provide different P:E ratio with the presence of high MP (Chapter 4). This has been extended to consider the effectiveness and economic benefit of specific supplements (i.e. different protein sources) on the basis of cost per unit carcass gain.

The hypotheses of the experiment were:

1. Animals respond to a supplement containing fishmeal in terms of rate of LWG and final body composition in a faster or slower way that differs from the response to other protein sources.
2. The starting liveweight influences the potential to respond to protein sources, lighter animals exhibiting greater response in lean growth.

6.2 Materials and methods

6.2.1 Animals and management

In 1995 winter, at The University of Melbourne's Mt. Derrimut Field Station, thirty two ten weeks old, early weaned male (cryptorchid) cross-bred autumn lambs (Dorset Horn x Merino) with an average liveweight 30 kg, were weighed, drenched with anthelmintics for the control of helminthes and injected with vitamin A, D and E, allocated into four groups by stratified randomization, housed and fed in individual pens.

In each group there were two subgroups with animals separated on to the basis that they were either above or below the median weight of the group.

6. 2. 2 Experimental design, feeds and feeding

The base diet was Oaten Chaff+Lucerne Chaff combination (2/1 W/W, 11/8 P/E) offered ad libitum. This basal diet was fed to all animals for 1 week to allow adaptation to the diet before supplementary treatments were commenced.

Group one was then slaughtered at the end of the adaptation period i.e. at the commencement of the supplementary experiment. Those animals were dissected, meat measurements made and body components weighed, frozen and subsequently processed for analysis of chemical composition as detailed in Chapter 2.

The remaining groups 2, 3 and 4 were then fed the following supplements for a period of 10 weeks.

Group 2 was fed with a supplement a combination of Fish Meal and Wheat Bran (FMWB) (1/2 by dry weight, 34.7/10.4 P/E).

Group 3 was supplemented with Protected Sunflower Meal+Wheat Bran (PSFMWB) (1/2 by dry weight, 24.2/11.2 P/E).

Group 4 was fed with Wheat Bran (WBRN) alone (17.0/10.1 P/E).

The mineral mixture was added to all feed types as described in Chapter 5.

The estimated MP values of these supplements are 43.6, 20.23 and 14.3 respectively as described in Chapter 4.

All forms of supplementary feeds were pelleted and fed at a level 1% of live weight. Supplements were offered every morning at the same time as the fresh allocation of roughage was provided, in separate bins. The feed residues from the previous day was removed and weighed back at the time of feeding to allow feed intake measurement.

After ten weeks animals were slaughtered and the same sequence of procedures as outlined above was applied for meat and carcass measurements.

Animals were shorn at the beginning and the end of experiment.

6. 2. 3 Measurements

6. 2. 3. 1 Intake, digestibility and liveweight

The intake of base diet and supplement were measured separately daily throughout the study. Liveweight of each sheep was recorded weekly.

During the feeding period, after all animals had been on the supplements for 30 days, animals were moved to metabolism crates for a period of 10 days and a digestibility and N balance study was undertaken as described by Neathery (1972). Urine and faeces were collected daily over 10 days, subsampled, cumulatively bulked and frozen until the analysis.

6. 2. 3.2 Carcass weight and body components

At the end of ten weeks of experiment when the heaviest animal was about 45 kg liveweight, all animals were shorn and then slaughtered, dissected and analyzed for chemical composition of the carcass with the standard methods outlined in Chapter 2 and 3. Animals were compared on the basis of effect of treatment on liveweight and composition at the liveweight achieved.

6. 2. 3. 3 Meat measurements

Meat measurements were made at the time of the slaughter by the method as described in Chapter 2 and 3.

6. 2. 4 Statistical analysis

Statistical analysis were made with Minitab in analysis of variance, one way ANOVA with LW as a covariate and 2 way ANOVA with treatments and subgroups or LW.

6. 3 Results

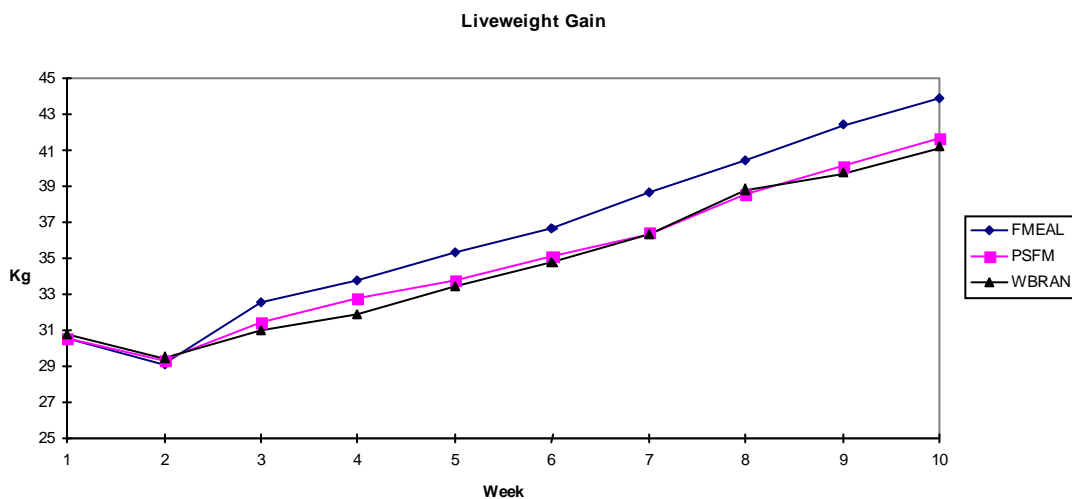
One WBRN lamb was dead in the third week of experiment from the causes not identified, no other animal appeared to be ill or disturbed.

Data reported here are the means of animals in treatment groups or in subgroups.

6. 3. 1 Growth rate and daily liveweight gain

FMLM animals grew significantly ($P<0.05$) faster than those in any other groups. Average growth rate across all treatments was; 220g/day/head for FMWB animals, 180g/day/head for PSFMWB animals, 180g/day/head for WBRAN group animals. Some of FMWB animals reached the target weight of 45 kg (Figure 6. 1).

Figure 6. 1.. Weekly live weights of animals throughout the experiment.



Final liveweights of FMWB animals were the greater compared to PSFMWB and WBRN. Daily LWG and empty body weight of FMWB were significant (Table 6. 1).

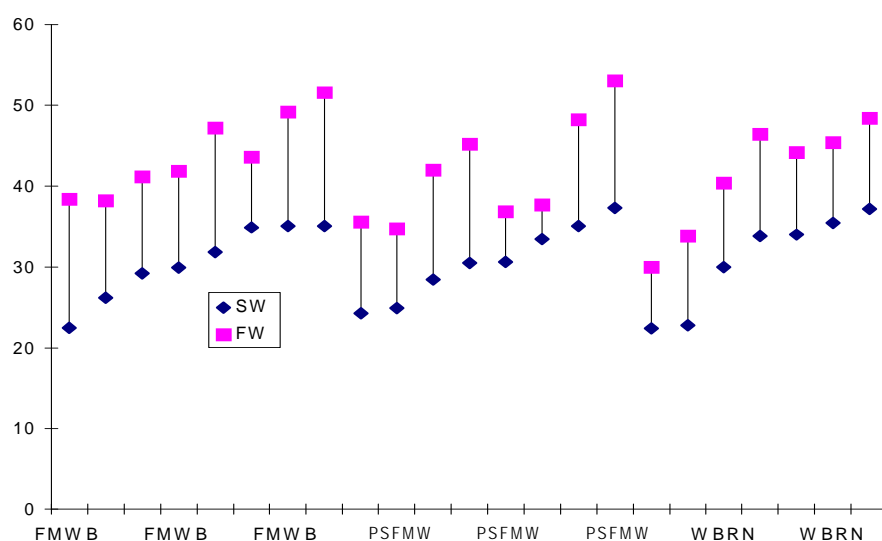
Table 6. 1. Liveweight, fasted liveweight, hot carcass weight and daily liveweight gain of animals.

	Initial ¹	FMWB	PSFMWB	WB	Sem ²	P
No.	8	8	8	7		
Final LW (kg)	27.7	44.0	41.7	41.0	1.54	NS
Fasted LW (kg)	24.8	40.9a	38.1ab	37.3b	1.84	**
Hot Carcass weight (kg)	14.3	19.6a	18.3ab	17.3b	1.12	**
ADG (kg/day)		0.22	0.18	0.18	0.039	*

¹Initial liveweight as covariate for final LW and DLG, ²pooled sem

FMWB animals were heavier and more uniform than other treatment groups animals (Figure 6. 2).

Figure 6. 2. Initial (SW) and final live weight (FW) spread of animals.



6. 3. 2 Intakes of feed and digestibility of ration components

Over all animals in each treatment there were no statistically significant differences in the intake or the digestibility of dry matter or the fibre (NDF) despite the tendency for some reduction in the proportion of supplement in the ration consumed in lambs fed

FMWB. Nitrogen intake was highest ($P<0.001$) in lambs fed FMWB and lowest in lambs fed wheat bran but this did not result in any significant difference in nitrogen digestibility. Fibre (NDF) intake was greatest in lambs fed WBRN.

Lambs fed FMWB showed nitrogen outputs well above ($P<0.05$) those of lambs fed either of the vegetable-based supplements. Urine nitrogen losses in lambs fed fish meal was almost twice ($P<0.001$) those of lambs fed wheat bran, and were higher per unit N intake than for lambs fed PSFMWB or WBRN.

Feed conversion efficiency (FCR) followed a similar pattern to that shown for nitrogen intake but did not differ significantly between diets.

Table 6. 2. Dry matter intake and digestibility and utilization of DM, N and NDF in lambs fed protein supplements.

	FMWB	PSFMWB	WBRN	Sem ²	P
No.	8	8	7		
Mean Liveweight (kg)	36.4	35.0	34.8	0.85	NS
Intake ¹ (g/d)					
Roughage I.	1036	900	981	0.39	NS
Supplement I.	349	335	355	0.03	NS
Nitrogen (g/d)					
Roughage	15	13	14	0.06	***
Supplement	17	13	9	0.016	***
NDF (g/d)	439	500	600	0.26	NS
g/kg DMI	55.7	55.7	62.9	17	*
Digestibility ¹ (g/kg)					
DM	621	611	601	9.9	NS
N	584	658	662	3.4	NS
NDF	404	368	421	18	NS
Nitrogen Output ¹ (g/d)	21.4	17	16.1	10	*
Urine-N Output ¹ (g/d)	13	9.14	7.9	7.9	**
N Balance ³	10.6	9.0	7.05	0.9	**
Feed Conversion Ratio					
Kg DMI/kg gain	4.7	5.0	5.2	0.31	NS
Metabolizable Energy Intake (MJ)	948	860	912	33	NS

¹Mean liveweight as covariate; ²pooled sem; ³N Balance = Intake N – (Uriner N Out + Faecal N Out)

6. 3. 3 Slaughter and carcass weight of animals

Carcass weights (Table 6. 1) were greater in lambs fed the FMEAL diet than in lambs fed either of the other forms of supplement. Carcass yield as a percentage of fasted liveweight was not influenced by diet (Table 6. 3) over all the treatment groups.

When analyzed for light and heavy subgroups, final liveweights ($P < 0.001$) and carcass yields ($P < 0.01$) were statistically significantly different between the light FMWB and PSFMWB animals (Table 6. 5).

6. 3. 4 Carcass characteristics and composition

The composition of the carcass was substantially altered by growth following supplementation and although there was no statistically significant differences between treatments there was a consistent trend toward deposition of higher contents of DM, fat and energy and a tendency toward a reduction in protein content per kg EBW as carcass weights increased (Table 6. 3). However, the carcass DM contents of FMWB animals seem approached chemical maturity (Moulton 1923) earlier than other groups, where we can observe a treatment effect but statistically non-significant. Carcass weight gains were greater in lambs fed the FMWB diet than animals fed either of the other forms of supplements. Carcass yield as a percentage of empty body weight was not significantly influenced by diet. With all supplements the composition of the carcass changed in a major way from the composition of the initial slaughter group. However, there were no statistically significant differences between supplement treatments over all animals. There was a consistent trend toward a reduction in protein content (amount and proportion) as carcass weight increased (Table 6. 5).

Table 6 3. Carcass yield and components of animals.

	Initial	FMWB	PSFMWB	WBRN	Sem ²	P
No.	8	8	8	7		
CW (kg)	14.3	19.6	18.3	17.3	1.12	NS
Carcass Component (%)						
Yield (%)	51.6	47.9	48.0	46.4	0.7	NS
DM (%)	43.6	49.4	48.2	45.6	1.7	NS
Fat (%)	53.0	63.4	62.6	59.3	1.4	NS
Protein (%)	40.6	31.6	32.7	35.1	1.6	NS
Energy (MJ/kgDM)	187	308	278	249	24	NS

¹Carcass weight as covariate for component composition; ²pooled sem.

No statistically significant differences were observed in either the weight or gain in weight of major carcass chemical components following supplementation (Table 6.4). Splitting into subgroups did not result in any significant differences between any treatments on basis of animal size (Table 6. 5).

Table 6 4. Carcass chemical composition of animals.

	Initial	FMWB	PSFMWB	WBRN	Sem ²	P
Component (kg)						
Fat	3.5	5.6	5.5	5.2	0.73	NS
Protein	2.4	2.95	2.78	2.63	0.03	NS
Ash	0.36	0.47	0.42	0.48	0.03	NS
Energy (MJ)	1265	2660	2525	2415	115	NS
Component Gain (kg)						
Fat		2.1	2.0	1.7	0.44	NS
Protein		0.55	0.38	0.23	0.13	NS
Ash		0.11	0.06	0.12	0.04	NS
Energy (MJ)		1395	1260	1150	191	NS

¹Carcass weight as covariate; ²pooled sem.

6. 3. 5 Liveweight and carcass components of subdivided group animals.

All animals grew and body compositions differed from the initial group. The target weight 45 kg was passed by most of the animals that had initial LW>median. FMWB animals were the group with highest final liveweight, liveweight gain, carcass weight fat percentage and fat depth. When we observe the major yields of animals divided into lighter and heavier sub-groups on the basis of starting weight (Table 6. 5), FMWB animals achieved heavier final weight, than those fed either the PSFMWB,

WBRN. The light FMWB animals reached 40 kg, but the other light sub groups in the other supplement treatments did not. All heavy animals at slaughter had high fat proportion and thick fat depth. Relating to FW, visceral organ weights and digestion tract (guts and intestines) weights were higher in the heavier sub-groups than the lighter sub-group of animals, but the difference was not statistically significant.

Table 6. 5. Initial weight, final weight and carcass components of light and heavy sub-group animals.

Variable	Initial		FMWB		PSFMWB		WBRN		Sem ²	P
	Light	Heavy	Light	Heavy	Light	Heavy	Light	Heavy		
IW kg	24.6	32.0	27.7	34.2	26.7	34.1	26.4	35.5	2.67	*
Final LW ¹ kg	-	-	39.8abc	47.9a	36.3c	47.1a	37.1bc	46.7ab	3.34	**
Gain	-	-	12.1ab	13.7a	9.6c	13.0ab	10.7bc	11.2abc	1.29	NS
SpGR % ³	-	-	49	40	45	28	39	31	3.41	**
CW kg	12.0	17.0	17.8ab	21.4a	17.2ab	19.5a	14.7b	20.1a	2.09	*
Fat %	48.9	56.9	62.9ab	64.4a	61.0ab	62.5ab	55.0b	63.6a	5.51	NS
Prot %	44.2	36.7	31.0b	30.9b	34.0a	32.5ab	35.6a	31.9ab	4.37	NS
Visceral W kg	3.28	3.75	4.67	5.96	4.68	4.72	4.44	4.92	3.27	NS
Gut&Intestine W kg	2.09	2.44	2.75	2.98	2.9	2.86	2.68	2.94	3.39	NS
GR mm	4.0	6.7	11.0a	12.2a	7.2bc	9.3bc	5.1c	9.6bc	3.24	NS

¹Final LW as covariate, ²Sem Pooled Sem. ³SpGR %³; Specific Growth Rate as percentage: linear regression of LW against time.

Results in the same row with different superscripts are significantly different at P<0.05.

Light starting weight animals' SpGR (specific growth rates) were significantly higher than heavier animals. FMWB light weight subgroup animals were superior to all other treatments.

6. 3. 6 Weights of Body Components

Following adjustment for differences in fasted liveweight there were few statistically significant (P< 0.05) differences in the weight of principal organs (Table 6. 6). The data showed a general tendency for lambs fed fish meal to display the heaviest of non carcass component weight and lambs fed wheat bran to have lower weights of these components. The induction of short-scrotum (cryptorchid) lambs did little to prevent the development of the testes which also increased (P<0.1) in weight with increases in liveweight.

Table 6. 6. Selected body components of animals.

	Initial	FMWB	PSFMWB	WBRN	Sem ²	P
No.	8	8	8	7		
EBW (kg)	24.8	35.1	32.8	31.4	1.84	**
Component (kg)						
Head & Feet	2530	3335	3015	3095	84	NS
Blood	1510	1990	1880	1860	86	NS
Skin ³	2540	3150	3015	2945	81	*
Heart	193	276	259	254	12	NS
Lungs	429	616	532	551	26	NS
Liver	568	785	667	663	22	NS
Kidney	120	139	127	124	5	NS
Spleen	55	72	63	60	3	NS
Diaphragm	125	178	171	164	6	NS
Abdominal fat	256	479a	437ab	312b	57	*
Perirenal fat	88	226	220	198	31	NS
Penis & testes	162	303	290	274	19	*
Visceral Organs	1800	1935	1790	1840	42	NS
Internal Fat	425	710	650	515	77	NS

¹Fasted liveweight as covariate; ²pooled sem., ³All animals were shorn before slaughter. Results in the same row with different superscripts are significantly different at P<0.05.

6. 3. 7 Digestive Tract

Forestomach weights increased following supplementation, with the greatest increase occurring in lambs fed FMWB (Table 6. 7). Differences in the weights of the small and large intestines were less obvious. Lambs fed FMWB held proportionately more digesta (740 v 680 g/kg gut content) in the forestomaches than did lambs fed the WBRAN ration. Calculations indicate that lambs fed FMWB also showed lower empty gut weights (77 v 85 g empty gut weight/kg fasted liveweight) and lower weights of gut contents (154 v 179 g/kg fasted liveweight) than lambs fed WBRAN (Table 6. 7).

Table 6. 7. Digestive organ weights of animals.

	Initial	FMWB	PSFMWB	WBRN	Sem ²	P
No.	8	8	8	7		
Empty BW (kg)	24.8	35.1	32.8	31.4	1.84	**
Full Weight (kg)						
Fore-stomachs	3045	5237	4968	4995	262	***
Small Intestine	1634	1704	1799	2010	89	*
Large intestine	936	1170	1260	1300	105	NS
Empty Weight (kg)						
Fore-stomachs	948	1245	1353	1186	101	***
Small Intestine	1127	1010	974	1147	75	NS
Large intestine	377	444	486	349	81	NS
Gut Contents (kg)	3162	5412	5214	5621	272	***
Empty Gut Weight (kg)	2453	2699	2813	2683	86	*

¹Empty bodyweight as covariate(EBW= FLW-gut content weights); ² pooled sem.

6. 3. 8 Meat Quality Characteristics

Diet type had little effect on fat colour characteristics. Meat colour intensity (L) was similar for all treatments but relative meat red (a) and yellowness (b) characteristics were reduced following all forms of supplementation in which age may be affective on formation of paler meat colour considering that all animals were supplemented with minerals. Eye muscle area showed no significant effects of diet-type.

Table 6. 8. Meat and fat colour, eye muscle area of animals.

	Initial	FMWB	PSFMWB	WBRN	Sem ²	P
Fat Color ¹						
L	64	77	75	75	4.8	NS
A	2.7	1.5	1.9	2.2	0.38	NS
B	6.6	5.8	5.0	6.0	0.73	NS
Meat Color ¹						
L	34	35	35	34	0.62	NS
A	19	17	17	16	0.50	***
B	8	5	5	4	0.55	***
Eye Muscle Area (mm)	1166	1239	1286	1278	71	NS

¹Initials as covariate; ²pooled sem;

6.4 Discussion

There was no significant difference between treated animals in FW and carcass components and small differences in DLW gain and EBW regarded as main groups. The specific growth rate of FMWB animals were superior to other treatment groups of animals. When the high and low liveweight sub-groups are considered, FMWB resulted with significantly fatter animals for heavier starting liveweights. The lighter animal sub-groups receiving FMWB ended up with larger, more uniform and leaner carcasses. Final LW of all heavy subgroups of treatment animals were greater than light sub-groups. The extra protein supplied by fishmeal in RUP and RDP fractions resulted a better liveweight gain for FMWB animals. The heavy FMWB and PSFMWB animals were gaining weight close to each other but the light PSFMWB animals were the lowest LW sub-group. The light FMWB group animals had achieved weights only slightly lower than the heavy sub-groups of PSFMWB and WBRAN animals.

The heavy sub-groups of all treatments were all fatter than the light animals. The biggest difference was between light and heavy WBRAN subgroups. The light FMWB animals were not leaner (less fat) than heavy PSFMWB and WBRAN subgroups. Also intra-abdominal fat content was highest for FMWB and lowest for WBRAN.

Fat depth of all groups and sub-groups broadly follows fat percentage, but FMWB light and heavy sub-groups were the thickest and than WBRAN heavy animals.

The protein content of light WBRAN animals were the highest and FMWB sub-group animals were the lowest.

The extra protein content of FMWB fed to animals resulted in a heavier but fatter carcass. PSFM reduced roughage intake probably because of high fibre content and probably the residual oil content affected rumen fermentation negatively.

WBRAN gave a reasonable liveweight gain and good carcass which contains lower fat and lower GR for light animals.

All light weight sub-group animals' specific growth rates were greater than heavy animals, especially the FMWB light group was significantly faster growing than any other sub-group animals ($P < 0.001$).

FMWB seems have resulted with an unexpected effect which was not defined in the hypotheses of the experiment, namely which it supported good growth. There was high gain of fat in both light and heavy animals that excess protein was broken down and some of it directed towards energy storage and fat deposition (Butler-Hogg and Cruikshank 1989).

As lean portions of raw meat contain 19 to 23 percent protein (Hedrick et al. 1989) and the other major variables are usually considered: moisture and fat, if there is an increasing proportion of one, there must be a decreasing proportion of one or both of the remaining variables. The major target of this study was to manipulate body composition for reducing fatness and improve the carcass protein deposition, that the amount of protein deposited in the animal body and economical value of the product becomes important.

Cost of feed and protein retention of this experiment are summarized in Table 6. 9. The animals consumed approximately the same amounts of supplements which contained different amount of protein with different degradability characteristics.

Table 6. 9. Cost of feed and protein retention per kg body protein content.

Supplement ^{1,2}	Cost/kg/\$	Intake kg	Intake cost \$	Carcass protein kg	kg protein cost \$
FMWB	0.398	20.6	8.20	2.95	2.78
PSFMWB	0.283	21.3	6.02	2.78	2.17
WBRAN	0.200	21.3	4.26	2.63	1.62

¹ The feedstuff prices were obtained from local feed dealers in Victoria and confirmed from Australian Trade Commission, Sydney NSW Australia databases.

² The cost of labour for the pelleting process was not calculated.

FM consuming animals achieved the heaviest carcass weights between the treatments. They were also the fattiest animals both in carcass content and abdominal fat. Above the basal costs of protein production, measured as saleable carcass protein, deposition

of 1 kg protein in FM animals cost \$2.78, PSFM/WB animals \$2.17 and with WB alone, \$1.62.

Chapter Seven: Final conclusions

Core concept behind the hypotheses being tested in this Thesis was:

- A. That lambs that are weaned and at early growth stage have a high P:E ratio requirement which cannot be met by pasture alone.
- B. Lambs that are not protein deficient in terms of achieving maximum growth rate will grow lean and fast.
- C. That lightest lambs in a group have a higher P:E ratio requirement, because,
 - 1. they are younger,
 - 2. they are restricted and showing compensatory growth; or
 - 3. they have sub-clinical infection or parasite infestation (MacRae 1979, Poppi et al. 1986) and need more protein.
- D. That heavier lambs have lower P:E ratio requirement because
 - 1. they have started to lay down fat,
 - 2. use extra protein inefficiently, partitioning as an energy source so that more N is excreted in the urine, and
 - 3. possibly partition protein gain to visceral organs and gut growth.

In conditions where high quality pasture growing, supplementary feeding has little significant effect on the growth performance of young sheep (Chapter 1 and 5). In the presence of sufficient pasture, animals tend not to respond to supplements unless there is a significant limitation to digestibility or nutrient balance. Weight gain of supplemented animals is therefore highly dependant on to the quality and quantity of the material present in the pasture and also to the nutritional qualities of the supplement.

Energy feeds such as barley grain produce a less stimulus to growth rate and more fat deposition (Chapter 3).

Animals respond to high P:E ratio feeds, especially to RUP and RUP supports faster growth of young animals with larger carcass and all other body components and compartments (Chapter 3 and 6).

Young or lighter weight animals respond and utilize high P:E ratio diets better than older or heavier weight animals, to produce leaner carcass (Chapter 6).

Protein supplementation to light and young animals results faster growing, heavier and leaner animals as a more uniform flock (Chapter 2, 3, 5 and 6).

Heavier animals perform, like mature animals, utilize the extra protein as an energy source and cumulate higher fat proportion in their body (Chapter 6).

The growth of the lighter animals may be due to compensatory growth as their specific growth rate was found significantly ($P < 0.001$) higher than the heavier animals at the same age (Chapter 6).

Fishmeal is a very good source of RUP with a steady degradation rate (1.5g/hour) in the rumen (Chapter 4). Heat generated during the pelleting process thought to improve protein resistance to rumen degradation with most of the feeds such as wheat bran, Lucerne meal.

Several lines of further investigation can be suggested by the results presented in this thesis.

The hypotheses of the Thesis was partly supported with the faster growth rates of light weight animals which are supplemented with high protein diets. Even the heavier animals slaughtered at the commencement of the supplementary feeding period were found fatter than lighter sub-groups. At the end of the feeding period, all heavier animals were fatter, there being a strong correlation between LW and fat depth. Despite this, the fat depth and fat content in their carcasses were in the acceptable range, so an advantage came with their greater carcass weight. The supplements fed to animals probably contained more enough additional energy than of their requirements for rapid growth and the P:E ratio was no great enough to support superior N retention.

The grazing only animals performed almost well as supplemented animals, probably because measured pasture figures did not represent effectively the actual available

plant potential in the paddocks, or the animals' selective grazing behavior manipulated to support quality of intake to a better utilization of the growing pasture. Having the information about the animals previous feeding history always helps for configuring a supplementary feeding strategy and for planned nutritional program. Therefore further studies are called for on: referring choice of supplement to a liveweight gain strategy; creating more uniform flocks by segregating the animals by weight or age more tightly into lighter, heavier and median groups, and treating them with differently organized supplements that may have some differential advantages on LWG and fatness. Measuring pasture potential accurately and allowing animals grazing with different stocking rates with or without supplements is a major challenge. The accurate measurement methods of pasture and supplement intake should be investigated in parallel to selective grazing behavior.

In configuring a business plan, considering market conditions and strategic positions; the type of the animal product must be selected before hand. This involves identifying a specific product highly valuable in determined seasons, or an all year round consistent product to maintain market needs consistently. These are both possible with feeding lambs in different models depending on planned systems for lambs different age or body weight conditions. Effects of lower and higher protein ratios on growth and carcass composition of light and heavy LW young sheep with the use of different protein supplements under limited energy conditions affects the growth and carcass composition. Different feeding regimes for different aged or body weight animals can be devised to produce high market value animals with lower costs.

As heavier or older animals end up with extra fat content in their carcass after a supplementary feeding period, the negative financial effects such as price reduction (penalty) for the animal because of excess fat and the amount spend for supplements must be considered.

All supplements come with a price. There is no direct financial benefit in feeding the higher priced supplements that have no extra beneficial effect on product amount or quality. Any financial benefit would rely on significantly greater carcass weight gain or increased value per kg of carcass.

The supplements and their prices in those periods used in the experiments reported in this Thesis are represented in Table 7. 1.

Table 7. 1. The prices^{1,2} of feeds used in the experiments.

Feeds	\$ Cost/tonne
BAR	220
WBRAN	200
LUPIN	370
PSFM	450
PSFM/WB*	282.5
FMWB*	398
FMLM*	632.5
Fishmeal	800
Lucerne meal	550

¹ The feedstuff prices were obtained from local feed dealers in Victoria and confirmed from Australian Trade Commission, Sydney NSW Australia databases.

² The cost of labour for the pelleting process was not calculated.

Lightest lambs if fed WBRAN can grow from 26 to 36 kg in 10 weeks and seem to have most suitable carcass. However, if target weight is 45 kg, time taken to get extra 8 kg “doubles” the feeding period, increases the total expenditure and also has an effect of stocking on the continuing grazing pressure of the pastures. Other factors have got to be taken into consideration including opportunity costs relating any other options.

Wholesale lamb meat prices are not readily predictable in Australia. The method of sale of lambs as yet does not result in stable prices, or in premiums for any class of carcass. It is not possible to predict what might be the result under a different form of marketing. If farmers are going to be satisfied that production of elite lambs is worthwhile and that feeding costs can be increased to produce to new specifications, the market supplied will have to lead that process.

In summary, grazing sheep can be fed and supplemented with a wide range of feedstuff. Age and liveweight of animal, the composition of base diet results a different carcass composition and though this has been difficult to show as statistically significant, but such effects will have economical value. (Chapter 3, 5 and 6). So the supplements selected for the sheep must be the cheapest one that achieves targets and specifications.

Animal feed producers have to avoid using high priced, high biologic value protein sources such as fishmeal, meat or blood meal. There may be some risks which are unknown today but on emergence will be found destructive. An example is Mad Cow

Disease (BSE), which has been associated with feeding infected meat by-products that have not been adequately heat treated during rendering or processing in preparation as component of animal feed.

The strategy adopted should therefore be: Try to use pasture potential as much as possible. Give animals, particularly young, light animals intended to grow fast, the opportunity to graze selectively. Animals tend to be selective in grazing in that they prefer green to dead material, leaves to stem and legumes to grasses and this preference provides a superior nutrient intake to second alternatives. Such “guidelines” have been incorporated into Decision Support Systems such as GrazFeed. In the pasture experiments reported in this Thesis, animals performed better than GrazFeed model predictions in utilizing the pastures, and there was evidence that predicted response to supplements on an energy source basis rather than on P:E ratio basis was misleading. GrazFeed overestimated barley and underestimated the affect of protein supplements, except in Experiment 4, where pasture conditions were very good.

There is a need now, not only to improve such Decision Support System models in relation to effects of strategic supplementation; but also to incorporate a capability to predict carcass weight, composition, fat depth and meat quality characteristics.

In this study there was no evidence that supplements used had any great influence on colour, tenderness or eye muscle area size that would resulting a significant downgrading of the quality.

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