EFFECT OF CONCENTRATE SUPPLEMENTATION ON DAIRY COW PERFORMANCE, WITH EMPHASIS ON TROPICAL FORAGES

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ABSTRACT

The objectives of the present study were to measure the effects of supplementation with concentrates which differed in their protein concentrations and protein degradabilities on the performance of dairy cows, with emphasis on tropical feeds. The degradability of protein in a range of feedstuffs was also measured and rumen metabolism was studied in sheep fed on diets which differed in protein degradability, at two different temperatures.

The first experiment (Chapter 4) was conducted in Thailand to determine the effects of concentrates which differed in their protein concentration (17%CP vs 30%CP) and protein degradability (0.65 and 0.53) on the performance of dairy cows fed on fresh pasture. The control treatment of feeding pasture only was also included. The yields of milk and liveweights gain were increased when concentrates were supplemented to pasture fed dairy cows both indoor and under grazing conditions. The response in milk yield to concentrate supplementation ranged from 1.2 to 2.0 kg milk/kgDM concentrate DM eaten. Increases in level of concentrate from 0 to 2.7 and 5.4 kgDM/cow daily resulted in decreases in response to supplementation (from 2.0 to 1.2 kg milk/kg concentrate DM eaten, compared with the unsupplemented group). The high protein (low degradable) concentrate tended to give higher responses in milk yield and liveweight gain per kg concentrate DM eaten.

The second experiment (Chapter 5) was also carried out in Thailand to investigate the effects of concentrates containing about 20% crude protein of different degradabilities (altered by inclusion of 0, 1 and 2% urea) on performance of dairy cows fed low quality tropical grass silage (5.2%CP and 48%DMD). The yields of milk and milk protein, and liveweight gain were significantly increased by Concentrate 2 (21%CP with 1% urea; 0.63 protein degradability) when compared with Concentrate 1 (19%CP with no urea; 0.57 protein degradability), Concentrate 3 (21.5%CP with 2% urea; 0.68 protein degradability) and Concentrate 4 (19.5%CP with no urea; 0.62 protein degradability). Silage intake was also increased in cows given Concentrate 2.

The degradability of DM and protein of 10 feedstuffs which are widely used in concentrates in Thailand were determined by the nylon bag technique at Khon Kaen University, Thailand (Chapter 6). The measurements used nylon bags inserted into fistulated cows given a diet of 4 kgDM urea-treated rice straw with an additional 2 kg of balanced concentrates. Between 45 and 55% of the crude protein content in cotton seed meal, maize and rice bran was effectively degraded in the rumen, compared with 63 to 69% for groundnut meal, palm meal, corn meal and sesame meal. Cotton seed meal could therefore be considered the most useful bypass protein source for use in feed supplements given to dairy cows in Thailand.

To determine the effects of environmental temperature conditions and the inclusion of urea in the concentrates on rumen metabolism, an experiment was conducted in New Zealand using sheep kept in controlled temperature room. Concentrates which differed in protein degradability (by inclusion of urea) were supplemented to sheep fed on low quality hay under 'mild' and 'hot' conditions. Hot temperature conditions had negative effects on DM intake, concentration of total VFA and degradability of protein but positive effects on respiration rate and water intake. The inclusion of urea in the concentrate supplements had fewer effects than the temperature conditions. Intakes of low quality roughage DM were reduced by hot temperature. High temperatures and low quality roughages are the two major factors contributing to the low production of animal in the tropics.

The final experiment was conducted in New Zealand to investigate the effects of a high protein-low degradable protein concentrate on the performance of grazing dairy cows fed generously on high quality autumn/winter temperate pasture. The high protein (low degradable) concentrate supplement significantly increased milk production. The milk yield response to the concentrate however, was lower than in the measured in the experiments in Thailand, probably because of the very high allowance of high quality pasture used in the New Zealand experiment.

It can be concluded that, in the present experiments, the major factor which contributed to differences in animal performance was ME intake, particularly for cows fed on concentrates. The effects of increased crude protein concentration or increased crude protein degradability in the concentrates on forage DM intake and on milk yield were variable. However, when a moderate level of low degradable protein concentrate was supplemented to cows on poor quality tropical grass silage, the effect of low degradable protein in the concentrate on increased milk production was evident.

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INTRODUCTION

1 INTRODUCTION

Dairy production in Thailand has a great potential to develop due to a large volume of demand in comparison to the present supply. At present, Thai dairy farmers only supply approximately 16% of the total consumption with the rest obtained from reconstituted milk powder imported from overseas (OAE, 1991). The present 16% supply is comes from the population of 101300 dairy cattle, with 44,450 cows in milk with an average yield of 8 kg/day for 300 days lactation (OAE, 1991). Increases in milk supply can be achieved by increases in population and in per cow production through improvements of genetic potential and feeding management.

Genetic potential of dairy cattle has been developed during the last three decades through the use of imported frozen semen from proved high genetic potential bulls from overseas. However, feeding management is likely to play a major role in low production per cow at present.

The low production per cow is probably due to poor nutritional management since the feeding standards adopted from temperate developed countries may not be suitable to the tropics. Generally, the cows milked in the tropics are fed on low quality native forages or agricultural byproducts, and are exposed to relatively hot environmental conditions. Such feed resources and environment probably contribute to the low production.

The natural low nitrogen concentration and digestibility of tropical pastures means that high animal production can not be achieved without the use of concentrate supplements.

Although, New Zealand dairy farming relies heavily on grazed pasture as the main source of feed, in some years significant pasture deficits can occur due to exceptional cold or wet winters reducing pasture growth rates. In addition, the animal production is often lower when grazed on pasture during autumn/winter than during spring. The probable unbalanced nutrient composition of autumn/winter pasture has been suggested (Wilson and Moller, 1993).

Traditionally, the requirements of dairy cows have been measured in terms of a certain minimum quantity of energy, expressed as metabolisable energy, and protein expressed as crude protein or rumen degradable protein plus undegradable protein, together with specific amounts of certain minerals and vitamins. However, more interest has recently been shown in the effects of variation in individual nutrients which contribute towards the supply of energy (Preston and Leng, 1987; Oldham and Emmans, 1989; Russell *et al.*, 1992). This is because production has been shown to be constrained through imbalanced nutrition, either in the rumen through inhibition of the rates of microbial protein production and/or fibre digestion (affecting intake and digestibility), or through an imbalanced nutrient supply to the body.

The correction of nutrient imbalances can be achieved through the supplements that contain specific nutrients.

A series of experiments was designed and initiated to investigate the responses in dairy cows' performance to the supplementation with concentrates which differed in protein content and in protein degradability (obtaining by inclusion of urea in the concentrates) both under tropical and temperate conditions. In addition, rumen metabolism and digestion were also studied under mild and hot conditions when supplements containing different levels of urea were fed to sheep on low quality hay.

CHAPTER 2

REVIEW OF LITERATURE

2 REVIEW OF LITERATURE

2.1 INTRODUCTION

Animal production can be affected by many factors including genotype, nutrition and environment. This review will focus on nutritional factors, with particular reference to the characteristics and nutritive value of tropical pastures, and the use of supplementary feeds with these forages.

Tropical pastures are generally characterised by low concentration of protein, low digestibility, low intake and low animal production. Forage intake, milk production and the use of supplements, in particular those containing protein will be discussed in relation to tropical forages.

The digestion and metabolism of nitrogen in the rumen will be reviewed, in relation to the degradability and nutritive value of different supplements.

2.2 CHARACTERISTICS OF TROPICAL FORAGES

Growth habit, perenniality, proportion and distribution of leaf and stem and flowering behaviour of pasture plants have significant effects on both the quantity and quality of forage available to grazing animals. Stobbs (1973) has suggested that the low animal production from tropical pastures, when compared with temperate pastures, may be caused by the more erect growth habit of most tropical grasses. The low bulk density of leaf in these pastures appears to restrict harvestability and intake of pasture by grazing animals. The effect of sward structure on animal performance has been extensively reviewed by Hodgson (1982).

When grasses flower and mature there is a decline in forage quality caused by the translocation of soluble carbohydrates from stem and leaves to the inflorescence, an increased content of lignified cell walls and a decrease in the ratio of leaf to stem

(Norton, 1982). Tropical grasses grown in warm environments have higher growth rates and usually progress to maturity rapidly, causing a rapid decline in nutritive quality (Wilson, 1982).

Tropical grass species (but not tropical legumes) have a C_4 photosynthetic pathway which results in higher fibre contents than in temperate grass species at comparable stages of growth (Norton, 1982). A feature of the C_4 grass is a thick-walled bundle sheath which is slowly or partially degraded by rumen microorganisms (Akin *et al.*, 1974). The parenchyma bundle sheath appears to be a major structural factor that often occupies a prominent part in the residue of C_4 grasses undergoing microbial degradation. Additionally, because of the photosynthetic pathway in C_4 grasses, the chloroplasts within bundle sheath are storage sites for plant starch. This starch, a rapidly utilisable source of energy by rumen bacteria and protozoa, is protected in the rigid sheath structure and is not available for microbial use until the bundle sheath cell wall is disrupted (Akin and Burdick, 1977).

Grasses possessing the C_3 pathway for photosynthesis grown in temperate climates have a higher ratio of mesophyll to vascular tissue than grasses which possess the C_4 photosynthetic pathway. The mesophyll is the tissue most easily degraded by rumen microorganisms and it is often readily penetrated by microbial enzymes (Hanna *et al.*, 1973).

The mesophyll cells in tropical grasses are more densely packed than those in temperate grasses (Carolin *et al.*, 1973). The lower ratio of mesophyll to vascular bundle sheath tissues in tropical grass restricts accessibility of plant cells to microbial digestion in the rumen (Hanna *et al.*, 1973), thereby decreasing the rate of digestion of the bundle sheath and the enclosed vascular tissue (Akin and Burdick, 1975). The high resistance offered to both mechanical and microbial degradation by the specialised leaf anatomy may partly explain the longer retention time of tropical grass forage in the rumen, and the consequent lower voluntary intake by ruminants consuming these plants (Thornton and Minson, 1973).

The lower tissue protein contents of tropical grasses compared with temperate grasses have been related to differences in their pathway of carbon fixation (Brown, 1978). The low protein content of tropical grasses poses a major limitation to intensive forms

of animal production. The protein content in both temperate and tropical grasses decline when grasses approaches maturity, and protein content at maturity is determined by initial protein levels in vegetative tissue, the rate and extent of decline and the final proportions of leaf and stem in the mature plant (Norton, 1982). Crowder and Chheda (1982) reviewed from 3 experiments and reported that the protein content declined from 17.2 and 13.4% at 4 weeks regrowth to 10.4 and 7.4% at 12 weeks regrowth in molasses grass and pangola grass respectively.

Tropical grasses have lower concentrations of soluble carbohydrates than do temperate grasses (Noble and Lowe, 1974). With increasing maturity, the soluble carbohydrate content of grasses increases with increased stem content.

The nature and concentrations of structural carbohydrates in plant cell walls are major determinants of forage quality. Cell walls form 30 to 80 percent of plant dry matter and vary as a source of energy. The cell wall content of leaves is usually lower than that of stem, and the cell wall content of grasses increases continuously during growth to maturity. Since leaf to stem ratio is lower in tropical grasses than in temperate grasses, tropical grasses have therefore higher cell wall content than temperate grasses. The high cell wall content of tropical grasses is also related to higher proportions of vascular tissue associated with the specialised anatomy of these C_4 plants (See above; Lyttleton, 1973; Norton, 1982).

Crude fibre has been the most common fraction used to designate the structural carbohydrate content of herbage, although neither hemicellulose nor pectins are included in this fraction (Lyttleton, 1973). Both tropical grasses and legumes are higher in crude fibre content than are temperate species. Mean values for the concentrations of crude fibre are: tropical grasses, 33.9%; tropical legumes, 30.3%; temperate grasses, 26.0%; temperate legumes, 25.3% (Norton, 1982).

Cellulose and hemicellulose are the major polysaccharides in the cell wall. The ratio of cellulose to hemicellulose is higher in tropical grasses (1.0-1.2:1.0) than temperate grasses (0.7-0.9:1.0), but this does not seem to affect cell wall digestibility (Minson, 1971; Ulyatt and Egan, 1979).

Tropical grasses and legumes tend to have higher lignin contents than temperate species (Harkin, 1973). The lignin content of the cell wall is the major determinant of the extent to which it can be digested. Lignin is a heterogeneous compound which is not digested either by ruminal microorganisms or by intestinal enzymes. By bonding to plant fibre it prevents swelling, thereby restricting entry of microbial digestive enzymes and consequently depressing fibre digestibility (Norton, 1982).

Minson and Wilson (1980) have determined from a survey of the literature that the mean dry matter digestibility for tropical grasses was 55.4% compared with 68.2% for temperate grasses. Similar, but smaller, difference were also reported for legumes.

2.3 EFFECTS OF SUPPLEMENTARY FEEDING

2.3.1 EFFECTS OF CONCENTRATE SUPPLEMENTATION ON PASTURE INTAKE AND SUBSTITUTION

There has been general agreement that when supplements are fed with unrestricted good quality pasture or forage, cows consume less pasture or forage although total feed intake is often increased (Bryant and Trigg, 1982; Meijs and Hoekstra, 1984; Stockdale and Trigg, 1985; Grainger, 1987). The term 'substitution rate' is used to describe the amount of reduction in pasture dry matter intake when each 1 kgDM supplement is consumed.

Grazing trials in the temperate region with lactating cows in early lactation have shown that feeding concentrates reduced herbage consumption (Jennings and Holmes, 1984; Meijs and Hoekstra, 1984; Arriga-Jordan and Holmes, 1986; Meijs, 1986; Stakelum, 1986a,b,c). The substitution rates varied between 0.03 and 0.79 kgDM/kg concentrate DM consumed. Earlier, Leaver *et al.* (1969) reported a substitution rate of 0.55 kg of herbage OM/kg concentrate OM eaten at restricted grazing with dairy cows.

In the tropics, however, few data for the effect of supplementary feeding on pasture intake are available. Combellas *et al.* (1979) reported the depression in herbage OM intake for each kg concentrate OM eaten of 0.53 kg which is in agreement with the range of 0.41-0.60 kg calculated from the equations of Holmes and Jones (1964). Cowan *et al.* (1977) showed that the substitution rate was 0.90, while Tayler and Wilkinson (1972) also measured a substitution rate of 0.94 for steers stall fed a pasture of 66% DM digestibility. One trial showed an increase in pasture intake due to formaldehyde-treated casein supplementation (Flores *et al.*, 1979).

The substitution rate and the amount of total DM intake can be influenced by the type of supplements, the feeding level of pasture and supplements, the quality of pasture and supplements, physiological state of animals and probably the interaction between these factors.

2.3.1.1 Composition of Supplements

Supplementary feeds are usually fed to dairy cows when herbage is in short supply. The effects of type of supplement on substitution rate are variable (Umoh and Holmes, 1974; Bryant and Trigg, 1982), probably due to differences in feeding level, herbage quality or balance of the whole diet between experiments.

some
Supplementation with highly digestible carbohydrate reduces rumen pH and fibre digestion (Mould *et al.*, 1983). If the rumen pH falls below 6.0 a substantial reduction of the proteolytic activity was noted as well as very low contents of proteolytic bacteria (Erfle *et al.*, 1982). High levels of easily fermentable carbohydrate result in a lower cellulolytic activity of the microorganisms in the rumen and lowers the rate of breakdown of fibrous particles in the reticulorumen. As a result, the increased degree of rumen fill with non-fermented residue may restrict intake of new feed (Steg *et al.*, 1985).

In an indoor feeding trial Sutton *et al.* (1984) on cows with *ad libitum* access to hay and concentrates (9.5 kgDM/cow daily) containing high starch or high fibre reported that daily hay DM intake was 8 kg/cow with a starchy concentrate and 8.9 kg/cow with

a fibrous concentrate. In contrast, in stall-feeding trials with grass silages, Castle *et al.* (1981) found no effect of concentrate type on forage intake whereas Mayne and Gordon (1984) observed lower intake of silage with a fibrous concentrate than with a starchy concentrate. However, in grazing experiments Meijs (1986) reported substitution rates of 0.45 and 0.21 kgDM/kg concentrate DM eaten with a starchy concentrate and a fibrous concentrate respectively.

Supplementation with a particular nutrient which is deficient in the diet can increase the intake of herbage resulting in a negative substitution rate. Protein supplementation, for example, can increase herbage intake when the herbage is deficient in protein (Kempton, 1983). Increases in DM and cellulose digestion and consequent increases in roughage DM intake were observed when a low-nitrogen basal diet was supplemented with either urea or casein (Orskov *et al.*, 1972; Mehrez *et al.*, 1977). Weidmeier *et al.* (1983) found increased cellulose and hemicellulose digestibilities on wheat straw rations supplemented with soyabean meal.

Reduction in substitution rate can be obtained by supplemention with high protein concentrate. Clements *et al.* (1989) found a reduction in substitution rate from 0.22 to o.07 kgDM silage/kg concentrate DM eaten when the concentration of protein in the concentrate was increased from 18 to 30%. Oldham (1984) suggested that increases in protein input resulted in increases in digestibility of the ration. He also reported that increases in DM digestibility in lactating cows offered rations of differing protein concentration were generally achieved when CP concentration was increased up to approximately 15% in the ration. Further increases in CP concentration in the ration usually had no additional effect on DM digestibility.

There have been a few recent reports showing increased forage intake by steers supplemented with 27% CP compared to 13% CP concentrates or no supplement (DelCurto *et al.*, 1990; Hannah *et al.*, 1991). In these trials the forage was of extremely low quality (2.3% CP, 79% NDF). Increases in the concentration of protein in the concentrates would probably have increased the supply of RDP in the ration and hence increased fibre digestion (Orskov *et al.*, 1972).

The effect of improved amino acid supply, or amino acid balance (by inclusion of bypass protein in the concentrate) in the animal on intake control mechanisms has been proposed by Egan and Moir (1965). If there is insufficient supply or imbalance of absorbed amino acids, this can limit metabolic pathways within the animal, reducing rates of utilisation of substrates and thus imposing a limit to voluntary intake (Forbes, 1986). It seems likely that deficiencies of essential amino acids result in reduced activities of key enzymes in metabolic pathways which are responsible for the removal of nutrients from circulation. These accumulate and may cause prolonged stimulation of chemoreceptors which form part of the negative feedback pathway to the centres of the brain controlling intake (Forbes, 1986).

2.3.1.2 Level of Feeding

The extent to which herbage DM intake is reduced in response to supplementary feeding under grazing condition is largely dependent on level of herbage allowance (Meijs and Hoekstra, 1984; Grainger and Mathews, 1989). Regardless of the type of supplement fed, the substitution rate is increased with increasing herbage allowance. Meijs and Hoekstra (1984) with concentrate supplemented to grazing cows, found that the substitution rate increased from 0.11 at a low herbage allowance to 0.50 at a high herbage allowance. Grainger and Mathews (1989) reported that pasture intake decreased by 0, 0.25 and 0.65 kgDM/kg concentrate DM eaten, at pasture allowances of 7.6, 17.1 and 33.2 kgDM/cow daily. A Similar relationship was also observed with a hay supplement (Eldridge and Kat, 1980; Wills and Holmes, 1988) and a silage supplement (Phillips and Leaver, 1985b).

The relationship between the amount of supplement consumed and substitution rate has been shown to be inconsistent. However, in general, the first increment of concentrate addition displaces very little forage, but as the amount of concentrate fed is increased, each additional unit of concentrate displaces a larger amount of forage (Meijs, 1981). In reviewing 11 zero grazing experiments covering the range 0-5.2 kg concentrates DM, Meijs (1981) found a mean substitution rate of 0.45. For a further increment of concentrates over the range 2.7-6.9 kg concentrate DM in the same experiments, the mean substitution rate was 0.60. However, this has not been

been confirmed in grazing trials with lactating cows (Meijs and Hoekstra, 1984), with beef cattle (Umoh and Holmes, 1974) and indoor trials (Taparia and Davey, 1970). In fact, Sarker and Holmes (1974), Combellas *et al.* (1979), and Stockdale and Trigg (1985) even found a decreasing substitution rate at higher concentrate intakes by grazing dry cows, heifers and lactating cows respectively.

2.3.1.3 Quality of Basal Roughage

The substitution rate can be affected by the quality of basal roughage. Meijs (1981) reviewed 11 indoor experiments and suggested that the low substitution rate of Masubuchi *et al.* (1976) could be attributed to the low digestibility (0.50-0.65) of roughage used and the resulting low herbage intake. Holmes and Jones (1964) showed a positive relationship between roughage digestibility and the depression in its intake by the concentrate.

2.3.2 EFFECTS OF CONCENTRATE SUPPLEMENTATION ON MILK YIELD AND COMPOSITION

Many authors have reviewed the effects of supplementary feeding on milk yield and milk composition in the temperate regions (Leaver *et al.*, 1968; Journet and Demarquilly, 1979; Bryant and Trigg, 1982), and in the tropics (Combellas *et al.*, 1979; Jennings and Holmes, 1985). Reviews by Leaver *et al.* (1968) and Jennings and Holmes (1985) concerning feeding of supplementary concentrates to dairy cows on temperate and tropical pastures respectively, gave mean response rates of 0.41 and 0.63 kg milk/kg concentrate eaten. The variation in response was very high with CVs of 50 and 63% respectively. The main sources of variation in response rate were the quality and quantity of pasture fed and the quality of supplement, all of which affected the degree of substitution of roughage by concentrate. With regard to the quality of pasture, tropical pastures, which are of lower digestibility than temperate pastures, were associated with greater response rates to concentrates. At low availabilities of pasture or forage, response rate was also increased and substitution rate decreased.

With regard to concentrate composition, Meijs (1986) has shown with dairy cows grazing temperate pasture that concentrates based on digestible fibre will produce greater yields of milk and, in particular, milk fat than starch-based concentrates. The most likely explanation for this is that starchy concentrates decrease rumen pH and reduce fibre digestion, resulting also in lower forage intakes (See 2.3.1.1).

The protein content of the concentrate is important first in supplementing tropical pastures where dry matter and crude protein intakes tend to be low (Kaiser and Ashwood, 1982a), and secondly where high levels of concentrates are fed stimulating milk production and raising protein requirements (Kaiser and Ashwood, 1982b). On temperate pastures, inclusion of fishmeal in concentrates has increased the response rate from 1.2 to 1.6 kg milk/kg concentrate DM consumed in high yielding cows (Le Du and Newberry, 1980). Supplementation of tropical pasture with protected protein has resulted in response rates of 2.2 (Rogers and Porter, 1978) to 2.4 kg milk/kg concentrate DM consumed (Stobbs *et al.*, 1977), the response being greater when the energy requirements of the cows are satisfied (Davison *et al.*, 1982).

The responses in milk yield (kg/kgDM) to the consumption of various classes of supplements, in the tropics are summarised in Table 2.1.1

With regard to the protein supplement, the responses ranged from 0.8 kg milk/kg soyabean meal DM eaten (Royal and Jeffrey, 1972) to 2.4 kg milk/kg formaldehyde treated casein DM eaten (Stobbs *et al.*, 1977).

With the exception of protein supplements, the average response is 0.45 kg milk/kg concentrate DM eaten. In most cases, the response in milk yield to 1 kg concentrate DM eaten is below the theoretical expectation. For example, 1 kgDM concentrate containing approximately 12 MJME should increase milk yield by approximately 2 kg, provided that there is no substitution and provided that all the extra energy is partitioned towards milk yield but not to body tissue deposition.

The major contributions of these observed lower response relative to theoretical estimation are the reduced pasture intake when concentrates were consumed (substitution rate), and the partition of some the extra energy intake towards body tissue synthesis.

Table 2.1.1 **Changes in yields of milk (kg/kgDM supplement) and milk fat (g/kgDM supplement) per unit of additional concentrate in the tropics.**

Reference	Type of Concentrate	Herbage Availability (kgDM/cow daily)	Herbage intake of unsupplemented cows (kgDM/cow daily)	Concentrate intake (kgDM/cow daily)	Total intake (kgDM/cow daily)	Substitution rate (kgDM/kgDM concentrate eaten)	Responses: Milk (kg/kgDM concentrate eaten)	Responses: Fat (g/kgDM concentrate eaten)
Butterworth (1961)	Balanced Concentrate	NR	NR	2.4	NR	NR	+0.33	+12
Aronovich *et al.* (1965)	Balanced Concentrate	NR	NR	1.9	NR	NR	+0.37	NR
		NR	NR	3.8	NR	NR	+0.42	NR
Royal and Jeffrey (1972)	Soyabean meal	NR	NR	1.1	NR	NR	+0.82	+27
	Maize	NR	NR	2.7	NR	NR	+0.49	+19
	Maize + Soyabean meal	NR	NR	3.8	NR	NR	+0.50	+18
Phipps (1973)	Balanced Concentrate	NR	NR	4.5	NR	NR	+0.27	-9
Guzman (1974)	Molasses	NR	NR	3.7	NR	NR	-0.16	-12
Esperance *et al.* (1976)	Balanced Concentrate	NR	NR	2.0	NR	NR	+0.57	NR
		NR	NR	4.0	NR	NR	+0.35	NR
Phipps and Holmes (1975)	Balanced Concentrate	NR	NR	2.0	NR	NR	+0.25	NR
		NR	NR	2.6	NR	NR	+0.30	NR
		NR	NR	4.6	NR	NR	+0.46	NR
Cowan *et al.* (1975)	Maize	NR	NR	3.6			+0.64	+7

Martinez *et al.* (1976)	Balanced Concentrate		NR	NR	3.1	NR	NR	+0.66	NR
			NR	NR	3.7	NR	NR	+0.40	NR
			NR	NR	6.9	NR	NR	+0.40	NR
Jeffrey *et al.* (1976)	Mixed Grain (Exp.2)		NR	NR	3.0	NR	NR	+0.37	+13
	Mixed Grain (Exp.3)		NR	NR	3.0	NR	NR	+0.50	+17
Stobbs *et al.* (1977)	Formaldehyde Treated Casein		40	NR	1.0	NR	NR	+2.40	+30
	Casein		40	NR	1.0	NR	NR	+0.40	+80
Cowan and Davison (1978a)	Maize		NR	NR	2.4	NR	NR	+0.62	+29
	Molasses		NR	NR	3.0	NR	NR	+0.50	+20
Cowan and Davison (1978b)	Maize		Low	NR	3.0	NR	NR	+0.80	+27
			High	NR	3.0	NR	NR	+0.27	+13
Martinez *et al.* (1978)	Balanced Concentrate		NR	NR	2.0	NR	NR	+0.89	+32
			NR	NR	3.0	NR	NR	+0.19	+11
Combellas *et al.* (1979)	Balanced Concentrate		18	9.1	3.0	10.1	0.67	+0.30	+9
			18	9.1	6.0	11.7	0.57	+0.27	+10
Flores *et al.* (1979)	*Luecaena luecocephala*		40	9.3	0.3	9.6	0.00	+2.00	+136
			40	9.3	0.7	9.7	0.43	+1.00	+48
			40	9.3	1.3	10.4	0.15	+0.54	+25
Lekchom *et al.* (1989)	Balanced Concentrate		12	NR	2.7	NR	NR	+0.70	+23
			12	NR	5.4	NR	NR	+0.46	+14
			12	NR	8.1	NR	NR	+0.38	+14
			12	NR	13.5	NR	NR	+0.29	+12
Davidson *et al.* (1990)	Meat and Bone Meal	4800 HM		NR	0.5	NR	NR	+1.60	+176

NR = Not Reported.

If the substitution rate is taken into account by expressing the response in terms of kg milk/kg extra DM actually eaten, the response rates would have increased. Due to limited data available on forage and total DM intake reported in this table, only one experiment (Combellas *et al.*, 1979) can be used to show the average response of 0.8 kg milk/kg extra feed DM (concentrate plus pasture) eaten. It is obvious that even when the response is expressed as kg milk/kg extra feed DM eaten, it is still lower than the expected theoretical response of 2 kg of milk. It suggests that about 40% of the extra energy was partitioned towards milk synthesis.

Clark (1975) summarised data from a number of experiments where the supply of amino acids was increased in the form of casein infused abomasally in lactating cows. Although gross efficiency increased with increasing milk yield, casein had no effect on partitioning or net efficiency of milk production. Orskov *et al.* (1977) observed increased milk energy outputs in excess of the energy in infused casein and further increases in tissue energy loss indicating that the added casein was causing a shift in the partition of nutrients from the diet and body stores toward milk synthesis. In a recent study by Whitelaw *et al.* (1986), casein infusion resulted in increased milk yield and greater tissue energy loss but appeared to have no effect on the partial efficiency of milk synthesis.

Rogers *et al.* (1979) reported yield responses of 0.5 and 2.0 kg milk/kg supplement for untreated or formaldehyde-treated casein fed to cows on fresh grass. Thomas *et al.* (1985) supplemented dairy cows with 12.3, 15.0 and 18.6% CP by varying the fish meal (low-degradable protein) concentration and reported that increasing the CP concentration in the supplements from 12.3 to 18.6% (no significant differences in total DM intake) increased yields of milk and milk protein. The responses were related to an increased measured flow of protein into small intestine.

Oldham *et al.* (1985) and Holter *et al.* (1985) have reported increases in milk yield in response to reducing dietary protein degradability while others (Crooker *et al.*, 1983; Janicki *et al.*, 1985; Blauwickel and Kincaid, 1986; Erfle *et al.*, 1986; Lundquist *et al.*, 1986) have shown no such response. The failure of additional ruminal undegradable protein to increase milk in the latter experiments may have been caused by a number of factors such as high dietary CP in the base ration relative to the cows requirements, or utilisation of low producing cows with low nutrient requirements, or escape protein

which was less available post-ruminally, or low ruminal ammonia concentration and decreased microbial synthesis or interactions with body energy mobilisation or utilisation (Nocek and Russell, 1987).

Oldham (1984) suggested that increased dry matter intake may be responsible for the positive relationship between protein intake and milk yield. Other studies measured milk production response to dietary crude protein intake (Claypool *et al.*, 1980; Cressman *et al.*, 1980; Edwards *et al.*, 1980; Roffler *et al.*, 1978; Nocek and Russel, 1987) and demonstrated that increasing dietary CP improved milk yield by increasing energy intake, and when increased dietary CP intake did not result in increased energy intake, only slight or no response in milk yield was observed (Cressman *et al.*, 1980).

There are many studies in which milk production increased with increasing crude protein in the diet (Gordon, 1974; Clark and Davis, 1980; Oldham, 1984). Oldham (1984) in summarising data from a number of studies, also demonstrated that much of the response is due to effects on ration digestibilities and increased intake. For example, data from 13 studies where dietary protein concentrations were varied, showed that milk production responses in 10 of the studies were due to increased energy intake. However, responses in three experiments were greater than could be explained by the increases in ME eaten and were probably due to altering either the efficiency or pattern of use of absorbed nutrients. The data of Tyrrell and Moe (1980) clearly show that increasing dietary CP results in increased ME from the diet. However, the data also show no significant effect of CP level on the net efficiency of energy utilisation for milk production. Studies by Roffler and Thacker (1983) and data from a number of studies summarised by Roffler *et al.* (1986) show responses in milk yield to increases in crude protein up to 200 g/kg ration dry matter with the effects mediated through increased intake of energy.

2.4 EFFECTS OF LEVEL OF FEEDING IN EARLY LACTATION

At a given level of feeding in early lactation, cows lower in liveweight or body condition score at calving produce less milk than cows calving at higher liveweight or condition score (Grainger *et al.*, 1982). The liveweight or body condition score at calving rather than the rate of change in liveweight or condition score prior to calving is the more important factor affecting future production (Rogers *et al.*, 1979; Grainger *et al.*, 1982; King *et al.*, 1985). Neither the type of diet nor the level of feeding precalving had a measurable influence on subsequent milk yield, milk composition or liveweight if the cows calved at similar weight or condition score (Hutton, 1972; Rogers *et al.*, 1981).

Changes in level of feeding are reflected in both milk output of the cow and in changes in body weight. Underfeeding in early lactation, for example, resulted in a reduction in milk yield, liveweight and condition score, and in an alteration of milk composition, not only during the time of underfeeding (immediate effect) but also after underfeeding had finished (carryover effect) (Broster, 1971, 1972; Grainger *et al.*, 1982; Broster and Broster, 1984; Broster *et al.*, 1984; Stockdale *et al*, 1987).

2.4.1 EFFECTS OF LEVEL OF FEEDING ON MILK YIELD AND COMPOSITION

2.4.1.1 Immediate Effect

Underfeeding in early lactation reduced yield and altered the composition of milk. Bryant and Trigg (1982) summarised trials from Australia and New Zealand and concluded that a decrease in DM intake of 1 kg caused a decrease in 39 g milk fat. The extent of this decrease is proportional to the duration and severity of underfeeding (Bryant and Trigg, 1979; Grainger and Wilhelms, 1979). In addition, the response in milk yield to a change in level of feeding is greater at a low level of feeding than at higher levels, is greater in higher than in lower yielding cows and is lower in mid-late

lactation than in early lactation (Broster *et al.*, 1981; Broster and Broster, 1984). It is interesting to note, however, that good feeding after calving will not entirely compensate for poor feeding prior to calving if the cows calve in low body condition score (Bryant, 1980; Grainger *et al.*, 1982; Treacher *et al.*, 1986).

Immediate effects of feeding level on milk composition are small. Bryant and Trigg (1982) suggested that underfeeding in early lactation had an unpredictable effect on the concentration of milk fat, but generally reduced the concentration of protein and solid-not-fat in milk.

2.4.1.2 Carryover Effect

The effects of underfeeding in early lactation on subsequent milk yield and composition have been reviewed (Broster, 1972; Bryant and Trigg, 1982; Broster and Broster, 1984).

Early works in New Zealand, Hutton and Parker (1973), Bryant and Trigg (1979) and Glassey *et al.* (1980) all found no significant residual effect on yields of underfeeding in early lactation. However, from New Zealand and Australia trials, Bryant and Trigg (1982) reported an average residual effect of 0.5, or less, times the immediate effect of underfeeding in early lactation. These can be compared with studies in the UK and Scotland, in which no residual effect (Blair *et al.*, 1981; Baker *et al.*, 1982), or a small and moderate carryover effect, up to 0.5-0.7 times the immediate effect (Wood and Newcomb, 1976; Johnson, 1977; Le Du *et al.*, 1979) were observed. One trial in the tropics, Combellas *et al.* (1979) also reported no residual effect of underfeeding in early lactation.

These results contrasted to the early information from New Zealand (Wallace, 1957; Patchell, 1957) and from the UK (Broster, 1972) which reported carryover effect of three or more times the immediate effect. The contrasting results may be attributed to the variation in the duration and severity of underfeeding, genetic merit, cows' condition and more important the subsequent level of feeding.

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Data on subsequent effects on milk composition have been shown to be inconclusive. Flux and Patchell (1957) reported a residual effect on milk fat concentration following underfeeding in early lactation whereas Grainger and Wilhelms (1979) did not find this, despite an apparent effect from current feeding. Broster (1972) summarised some early evidence showing a residual effect on protein and lactose concentrations in milk. Steen and Gordon (1980a,b) and Glassey *et al.* (1980) reported no residual effect on milk composition.

2.4.2 EFFECTS OF LEVEL OF FEEDING ON LIVEWEIGHT AND BODY CONDITION SCORE

2.4.2.1 Immediate Effect

Underfeeding in early lactation generally reduced body weight and condition score (Bryant and Trigg, 1979; Grainger *et al.*, 1982). An average of 174 g extra liveweight, with a range of 27-570 g, was associated with an extra 1 kgDM intake in trials summarised by Bryant and Trigg (1982). The variability of response may be attributed to differences in the extent of partitioning of feed between milk and body gain. Cows calving in low body condition, for example, will use a greater proportion of the feed for liveweight gain but a smaller proportion for milk production than those with higher body condition at calving. Also as a cow approaches its potential milk production an increasing proportion of the extra feed consumed will be partitioned towards liveweight gain and thus more feed will be required to produce extra milk production (Broster and Broster, 1984).

It should also be noted that at a given level of intake the greater the yield potential of the cow the smaller the body gain and in conformity with this, the greater the partition of additional nutrients to milk than to body by the high yielding cows (Broster *et al.*, 1975).

2.4.2.2 Carryover Effect

Cows fed less generously in early lactation gained more weight in mid lactation than did the previously better fed cows (Bryant and Trigg, 1979; Grainger and Wilhelms, 1979; Stockdale *et al.*, 1981). Grainger *et al.* (1982) reported that improved feeding in weeks 1-5 of lactation conserved body tissues, but better body condition at calving was associated with greater body loss in this period. In weeks 6-20 on equal feeding, change in body condition score was inversely proportional to feeding level in weeks 1-5 and the cow in better body condition at calving continued to loss more condition score. Broster and Thomas (1981) reviewed 46 trials and concluded that the cows fed poorly in early lactation gained 0.15 kg/day more weight in mid lactation than those well fed throughout.

2.5 FACTORS AFFECTING THE INTAKE OF RUMINANTS

The physical and metabolic factors affecting intake in ruminants have been extensively reviewed by a number of authors (Campling, 1970; Jones, 1972; Baile and Forbes, 1974). Physiological factors such as age, sex and productive state of the animal which affect herbage intake have been discussed by Bines (1976) and Weston (1982). Management factors and environmental factors such as climate, which may affect the intake of animals have been reviewed by Webster (1976) and Weston (1982).

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Voluntary food intake of animals is influenced by two main groups of factors, metabolic factors - factors which influence the animal's requirements for nutrients and its ability to metabolise absorbed nutrients, and physical factors - factors which influence the animal's ability to consume the feed, to accommodate and digest it in the digestive tract (Baumgardt, 1970; Bines, 1971). For grazing animals the regulation of food intake is determined by the inter-relationship between these two factors and behavioural factors (Hodgson, 1977).

2.5.1 METABOLIC FACTORS

The control of food intake can be considered as a component of the homeostatic regulation of energy balance between the animal and its environment (Baumgardt, 1970; Baile and Forbes, 1974; Baile and McLaughlin, 1987). In general the animal attempts to maintain a constant energy balance by changing food intake in proportion to its energy requirement and its altered physiological and environmental circumstances (Baile and Forbes, 1974).

Physiological control involves the potential feedback of the end products of digestion and metabolism to neural receptors in the brain. The receptor sites for the feedback control system which inform the brain about the nutritional state of the body apparently originate in the gastrointestinal tract, hepatic-portal system, adipose tissue and/or peripheral and cerebrospinal fluid (Baumgardt, 1970; Forbes, 1980).

Volatile fatty acids rather than glucose are the main products of energy digestion in ruminants and are possible components of the food intake regulation system (Baile and Mayer, 1970; Bines, 1971; Van Soest, 1982). Propionate and acetate are recognised as possible feedback signals of satiety in ruminants (Baile and Mayer, 1970) whereas butyrate is less important. The role of lactate is controversial, probably depressing the motility of the stomach (Forbes, 1980).

It has been suggested that the fall in rumen pH is involved in the cessation of intake (Kaufmann, 1976), although, as for the free fatty acids (Baile and Forbes, 1974) in the short term, there is little information to show if they are a cause rather than an effect of changes in feeding.

2.5.2 PHYSICAL FACTORS

With ruminants fed roughage diets, food intake is restricted primarily by rumen capacity since it is evident that ruminants fed bulky and fibrous feeds may stop eating before they have consumed sufficient nutrients to obtain the dietary energy required by

their genetic potential for production (Campling, 1970; Bines, 1971; Meijs, 1981). The physical limitation is related to the distention of the reticulorumen and rate of disappearance of digesta from the reticulorumen.

2.5.2.1 Distention of the Reticulorumen

Ruminants fed a large proportion of roughage consume to a constant rumen fill (Campling, 1970). The size of the rumen is partly determined by the size of the abdominal cavity, which appears to be limited in the extent to which it can stretch (Bines, 1971). It appears that the rumen capacity can be affected by foetal enlargement and fat deposition within the abdominal cavity, and this is associated with a reduced intake by animals (Forbes, 1980). There are stretch receptors in the rumen wall but the exact mechanism of transmission still remains unknown. The probable mechanisms are discomfort and stimulation of the humoral intake regulating factors (Van Soest, 1982).

The physical limitation of space in the gastrointestinal tract implies that volume rather than mass is of importance (Raymond, 1969; Waldo, 1986). Physical controls are primarily related to the capacity of the digestive tract (Freer, 1981), to the fibre content of the feeds and to the rate of degradation and passage, therefore the indigestible fraction of the DM is the major physical factor limiting intake (Chase, 1985).

In addition the physical properties of feed will influence quantities eaten at meals and patterns of eating. Higher density grains, for example, are likely to be consumed in large amounts in meals with low frequency, while low density straw diets are likely to be eaten in more frequent meals of small amounts (Baile, 1975).

However, the role of gut fill as the control mechanism for food intake is still controversial, and it has been associated with the type of diet.

2.5.2.2 Rate of Disappearance of Digesta from the reticulorumen

The rate at which digesta passes from the reticulorumen depends on the chemical composition of the feed, the rate at which the feed is broken down physically (mastication and rumination) and chemically (microbial and enzymatic digestion), the capacity of muscular contraction of the gut and the size of the reticulo-omasal orifice (Meijs, 1981; Ulyatt *et al.*, 1985). Retention of feed in the reticulorumen allows substantial microbial fermentation to take place, with over 60% of OM digestion occurring in the reticulorumen (Ulyatt *et al.*, 1985). Retention time is influenced by a number of dietary factors such as the amount of feed consumed, physical form of the forages, forage:concentrate ratios, fibre content and physical nature of the fibre (Freer, 1981; Shaver *et al.*, 1986).

Factors which are involved in the movement of particles from the reticulorumen include size of particles, density of particles, rate of reduction in particle size, cell wall content of the feed, hydration time, pH and osmotic pressure, strength and frequency of ruminal and abomasal contractions (Shaver *et al.*, 1986).

Undigested material can pass through the reticulo-omasal orifice only after being reduced to fine particles i.e. less than 2.0 mm. The critical size of particles is relatively insensitive to changes in digestibility, physical form of the feed, intake, type of pasture or liveweight of the animal. The amount of material passed per contraction of the reticulum rather than the particle size has been suggested to be probably more important in relation to rate of passage from the reticulorumen (Shaver *et al.*, 1986).

2.5.3 BEHAVIOURAL FACTORS FOR GRAZING CATTLE

The following section will concern the effects of sward characteristics and herbage allowance on the herbage intake of grazing ruminants.

Traditionally accepted theories on the mechanisms of intake control in stall fed ruminants apply to the grazing animal (Arnold, 1970; Freer, 1981). However, the

grazing animal is faced with the additional tasks of searching for, prehending and harvesting the herbage. Therefore, the main differences between grazing ruminants and those indoor feeding ruminants are the accessibility of feed, the ability of ruminant to take large bites and thus to consume herbage rapidly to satisfy the large quantities required in a short time.

When the quantity of herbage available is abundant (*ad libitum* intake) the nutritive value of the herbage is most important in determining intake through its effects on grazing behaviour and the distention mechanism. Where abundant herbage with a very high nutritive value is present, metabolic mechanisms are most likely to control intake. When the quantity of herbage available is low, herbage quality may have little effect on intake, and intake is most likely to be limited by grazing behaviour constraints (Hodgson, 1977; Combellas and Hodgson, 1979; Meijs, 1981).

Herbage intake in a grazing situation can be partitioned into its behavioural components (Allden and Wittaker, 1970), namely:

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

where the intake of herbage (I) is a product of the amount of herbage eaten per bite (IB), the number of bites per unit time (RB) and the amount of time spent grazing (GT).

The variation in IB is usually greater than variations in either RB or GT (Stobbs, 1973; Hodgson, 1981) and appears to be the most sensitive component to variations in sward conditions (bulk density, sward height, leaf/stem strength, sward structure). Since any compensating changes in RB or GT are usually limited, IB is likely to be a major determinant of daily herbage intake (Leaver, 1985; Hodgson, 1985).

The GT for a cow rarely exceeds 10-12 hours/day (Leaver, 1985; Poppi *et al.*, 1987), otherwise grazing would interfere with rumination time and other behavioural requirements. In the short term, the rate of herbage intake per minute of grazing time (RB x IB) falls steadily with increasing proximity of the grazed horizon to the ground level (Hodgson, 1977), because IB decreases rapidly as pasture height/mass decreases.

Supplementation has been reported to reduce GT by 9-38 minutes/kgDM of supplement for grazing cows supplemented with concentrates (Sarker and Holmes, 1974; Journet and Demarquilly, 1979; Arriga-Jordan and Holmes, 1986), silage (Phillips and Leaver, 1985b), or Hay (Phillips and Leaver, 1985a).

2.5.4 PASTURE FACTORS

2.5.4.1 Herbage Mass

Herbage mass is important for continuously grazed stock whereas daily herbage allowance is more important for rotational grazed cows because both effectively control the quantity of herbage available for grazing each day.

With rotational grazing, increases in herbage mass per unit area have been reported to cause increases in daily herbage intake (Hodgson, 1975; Jamieson and Hodgson, 1979; Stockdale and King, 1983; Zoby and Holmes, 1983; Forbes and Hodgson, 1985; Stockdale, 1985), while other studies have reported decreases or no change (Hodgson *et al.*, 1977; Reardon, 1977; Bartholomew *et al.*, 1981; Hodgson, 1977; Meijs, 1982). However, many examples have shown the relationship between herbage mass and herbage intake to be asymptotic (Hodgson, 1977; Combellas and Hodgson, 1979; Hodgson and Jamieson, 1981; Meijs, 1982). Such relationship indicates a constant increase in intake, if the response is linear, or a declining incremental increase, if the response is curvilinear, to a point - the asymptote - beyond which there is no further increase in intake. This decline in herbage intake, or total lack of any further increase beyond the asymptote is generally related to the decrease in herbage quality (Meijs, 1981; Stockdale, 1985) associated with pasture aging.

However, at a given herbage allowance, herbage intake is unlikely to be affected by the variation of herbage mass offered to lactating cows (Holmes, 1987) or dry cows (Holmes *et al.*, 1979). Combellas and Hodgson, 1979) confirmed the finding of Reardon (1977) that herbage intake was not affected by herbage mass within the range of 2000-4000 kgDM/ha but above this range intake declined progressively.

2.5.4.2 Herbage Allowance

For rotational grazed stock, herbage allowance (HA) has been shown to be an important determinant of the herbage intake and consequently of the animal performance of lactating cows (Combellas and Hodgson, 1979; Le Du *et al.*, 1979; Bryant, 1980; Glassey *et al.*, 1980; King and Stockdale, 1984; Mitchell, 1985; Stockdale, 1985) or non-lactating cows (Holmes and McLenaghan, 1980; Ngarmsak, 1982).

The relationships between HA and herbage intake, and between HA and animal performance have been suggested to be asymptotic (Combellas and Hodgson, 1979; Bryant, 1980). Herbage OM intake approaches a maximum at an allowance 4 times greater than the amount actually consumed (Hodgson, 1976), but only starts to decline markedly when HA is less than twice intake for lactating cows (Le Du *et al.*, 1979). In contrast, Combellas and Hodgson (1979) reported that herbage intake of grazing cows was near maximal when grazing efficiency, defined as herbage intake expressed as a proportion of the herbage allowance, was 50% or less.

Associated with increase in HA is an increase in residual herbage mass (RHM), and HA or RHM can be used to indicate herbage intake (Le Du *et al.*, 1979; Holmes, 1987). The effect of HA can be affected by pasture species (Stockdale, 1985), herbage mass (Combellas and Hodgson, 1979), season (Holmes, 1987) and quality (Hoogendoorn, 1987). To avoid part of that variability, Butler *et al.* (1987) suggested that HA should be expressed in terms of green leaf allowance.

2.5.4.3 Herbage Digestibility

As a general principle, digestibility is a satisfactory way of examining nutritive value and its influence on the amount of food intake by an animal (Hodgson, 1977). It will be determined by the pasture species present, stage of growth and management imposed upon the pasture (Baker, 1976). Factors affecting herbage digestibility have been reviewed by many authors (Raymond, 1969; Reid *et al.*, 1980; Minson, 1982).

Digestibility is a major determinant of pasture quality, and consequently it can affect animal performance (Holmes, 1987). Hodgson (1977) showed a linear and constant rate of increase in herbage intake over a range of digestibilities up to OM digestibilities of 80-83% for grazing animals. However, in most experiments quoted by Hodgson (1977), digestibility was confounded by changes in season and time of year, and also by the physiological state of the cows. The relationship is therefore imprecise and it is not a good predictor. It seems that the effect of digestibility on herbage intake is related to rate of passage of feed through the digestive tract.

2.5.5 ANIMAL FACTORS

2.5.5.1 Size, Liveweight, Body Condition, Age and Genotype

The size of animal is critical in determining the volume of the abdominal cavity which is related to rumen capacity (Bines, 1979; Meijs, 1981). In addition, the size and liveweight of animals are highly correlated. Voluntary intake is therefore positively related to liveweight. However, for adult animals liveweight could be an imprecise scaler with respect to body size because of differences in gut fill or fat content although it is generally reported that the heavier animals eat more (Bines, 1976, 1979; Meijs, 1981).

The relationship between feed intake and liveweight may be affected by the confounding effect of the frame size and body fatness. For example, at any given size of animals the fatter animal is also heavier, therefore, intake is often inversely correlated with body weight because increased fatness causes decreased intake (Forbes, 1986). It is also evident that, at a comparable liveweight, thin cows at calving ate more than fat cows (Broster and Broster, 1984).

The age of the cow influences its feed intake in addition to any consequent effect of age on body weight. Feed intake increases as animal grows, but not in direct proportion to liveweight (Forbes, 1986).

The variation in feed intake associated with genotype can be explained by differences in body weight and in level of milk production (Owen, 1988). For grazing cows, high breeding index (HBI) cows ate more feed (6-20%) during the early part of lactation than did low breeding index (LBI) cows (Holmes and McMillan, 1982). It is of interest to note that for the Friesians, HBI cows were lighter than LBI cows but ate more feed per cow or per $kg^{0.75}$ whereas Jersey HBI cows were heavier than LBI cows and ate more feed per cow or per $kg^{0.75}$ (Holmes *et al.*, 1985; Bryant, 1985).

2.5.5.2 Effect of Pregnancy

During pregnancy the volume and nutrient demand of the conceptus progressively increase and the dam's endocrine status changes (Forbes, 1970, 1971). Increases in intake in early and mid pregnancy (Forbes, 1971; Bines, 1971, 1976) might be caused by increases in metabolic rate, by the growth of the dam, by a possible increase in the rate of passage of the feed, by the energy requirement of the developing foetus or by elevated progesterone levels in the blood.

It is generally accepted that the intake falls as parturition approaches regardless of the type of diet (Forbes, 1971; Journet and Raymond, 1976; Meijs, 1981). A decline of 0.2 kgDM/week during the last 6 weeks of pregnancy was found by Journet and Raymond (1976). The decline in intake at this stage was probably due to a reduction in volumes of the abdominal cavity caused by physical compression of the uterus on the rumen (Baile and Forbes, 1974; Bines, 1979), and/or abdominal fat and endocrine changes (Forbes, 1971).

2.5.5.3 Effect of Lactation

Many reports have shown that lactating cows ate more than non-lactating cows (Hutton, 1963; Leaver *et al.*, 1968; Bines, 1976; Hodgson, 1977), regardless of type of diet. On average lactating cows consumed 42% more than non-lactating cows of the same liveweight (ARC, 1980), although the effect of pregnancy was probably

confounded in some reports. It has been suggested that the apparent greater intake was probably due to hypertrophy of the alimentary tract (Leaver, 1985) or to hormonal differences (Freer, 1981).

Most studies of the feed intake in lactating animals have shown that there was a positive relationship between the level of milk production and feed intake (Bines *et al.*, 1977; ARC, 1980; MAFF, 1984). Feed intake and milk production show a different pattern of variation over the lactation. Milk production rises rapidly immediately after parturition and usually reaches a peak between days 35-50, and thereafter declines steadily whereas food intake increases to reach a peak at an average of 16 weeks after parturition (Bines, 1976, 1979), developing a lag of energy intake balance; reasons are incompletely established (Meijs, 1981). It has been suggested that the factors are of physical origin (Bines, 1976), abdominal fat (Journet and Raymond, 1976), delay of hypertrophy of gut wall, liver (Bines, 1979), alimentary tract or endocrinological factors (Meijs, 1981).

Taking the whole lactation period, however, feed intake is likely to show a positive relationship to lactation milk yield, although other complicating effects may cloud this relationship (Owen, 1988). Over a lactation, multiple regression studies indicate that when other factors are taken into account, for each increase of 1 kg in lactation yield the dry matter intake of the cow increased by 0.5 kg (ARC, 1980).

2.5.6 EFFECT OF SUPPLEMENTARY FEEDING

The effects of supplementary feeding on the quantity of forage eaten, and on total feed intake, have been discussed previously in Section 2.3.1.

2.6 RUMINAL DIGESTION

Digestion is a complicated process in the ruminant. The rumen is the largest stomach encountered by the feed and accounts for about 60% of digestion. The processes occurring within the rumen therefore dictate to a large extent the nature of the nutrients available to the animal.

Digestion in the rumen is by microbial fermentation, the important feature of ruminant digestion being the ability of the microorganisms in the rumen to digest the complex plant carbohydrates, cellulose and hemicellulose.

The rumen environment appears to be controlled by the type and quantity of food eaten, salivation and rumination, diffusion or secretion into the rumen, absorption of nutrients from the rumen and passage of material down the digestive tract (Preston and Leng, 1987).

Neutral conditions in the rumen are maintained by continual adjustment of the pH of the ruminal fluid by the above processes, thus ensuring continuous fermentation. The biomass of microbes in the rumen is maintained at a constant level by the passage of microbes down the digestive tract, and also by death and lysis of the microorganisms within the rumen (Preston and Leng, 1987).

The microbial ecosystem in the rumen is complex and highly dependent on diet. In the rumen, the molecular structure of plant cell walls is broken down by anaerobic bacteria, protozoa and fungi. The anaerobic bacteria are the principal agents for fermenting plant cell wall carbohydrates but the anaerobic phycomycetous fungi may be extremely important (Bauchop, 1981). There appears to be a close relationship between fungi and the other microbes in the rumen since the fungi appear to be the first organisms to invade plant cell walls, which allows bacterial fermentation to start and to continue (Bauchop, 1981).

In the rumen, the ingested feed which is previously broken down in the mouth during chewing mixes with rumen liquor and the residues of the previous meals and is subject to breakdown by several processes; microbial digestion, rumen contractions and further chewing following regurgitation during periods of rumination.

The rate of breakdown in the rumen is dependent on the physical and chemical composition of the feed. A high proportion of soluble constituents in the feed usually results in a quicker breakdown than a high proportion of insoluble structural components.

Ruminal digestion is the product of the rate of ruminal digestion of the digestible organic matter and ruminal retention time (the reciprocal of the fractional passage rate) of digesta. Rate of digestion is dependent not only on bacterial attachment and action, but also on the chemical properties of the substrate.

2.6.1 EFFECT OF RUMEN pH ON RUMINAL DIGESTION

Rate of digestion of fibre can generally be decreased by a low ruminal pH. This may be due to the reduced prevalence or activity of cellulolytic species (Russell *et al.*, 1979). By increasing ruminal pH, buffers may increase ruminal fibre digestion, either by reducing the lag time (the time required for the inoculation and elaboration of bacterial attachments to the substrate (Mertens and Ely, 1979) or by increasing the rate of digestion. Effects of ruminal digestion on rate of starch digestion are not well defined. Feeding buffers to increase ruminal pH has reduced the extent of ruminal and total tract starch digestion (Erdman *et al.*, 1982; Rogers and Davis, 1982). This could be attributed to either a reduced rate of starch digestion when ruminal pH increases or a decreased time of starch exposure to digestion in the rumen associated with an increased rate of passage of particles.

Rumen pH is normally between 5.5 and 7.0. As reviewed by Tamminga (1979) the evidence suggests that the optimum pH for both proteolysis and deamination is between 6.0 and 7.0. There are reports of lower pH optima for ruminal proteases and deaminases, but since activity of both will be largely dependent upon total bacterial

numbers, rumen pH in a range between 6.0 and 7.0 should be compatible with maximum microbial activity. Under most feeding situations, pH in the rumen is in a range where extensive breakdown of dietary protein can occur.

2.6.2 EFFECT OF PASSAGE RATE ON RUMINAL DIGESTION

Rate of passage is a 'proportional rate', and calculated by dividing the actual outflow from the rumen (ml/h or g/h) with pool size (ml or g in the rumen). It is often multiplied by 100 to express in terms of percent passage per unit of time (%/h). Passage rate can be combined directly with fractional digestion rate of potentially digestible material to calculate the extent of ruminal digestion (Waldo *et al.*, 1972). Ruminal escape of potentially digestible material as a proportion of flow is equal to the passage rate (/h) divided by the sum of the fractional rates (/h) of passage and digestion of potentially digestible material. For example, if the fractional passage rates were 0.10 /h and digestion rates were 0.05 /h, then the extent of ruminal escape would be 67%.

Level of feed intake can affect the rate of passage. As DM intake increases, ruminal liquid volume, DM percentage in ruminal contents and rate of passage all increase (Kennedy and Milligan, 1978; Tamminga, 1979 ; Evans, 1981). Increases in volume and DM content of the rumen will reduce the impact of feed intake on ruminal passage rate. Pregnancy, exercise, temperature, frequency of feeding and even time of day alter ruminal volume or motility and thereby change rate of passage.

2.6.3 EXTENT OF RUMINAL DIGESTION

The extent of ruminal digestion is generally assumed to be more dependent on ruminal digestion rate that on ruminal passage rate. Certainly, the range is greater for the former rate constant than it is for the latter. On a percentage basis, the feed components most affected by a change in passage rate are those which are rapidly, but not completely digested in the rumen. For example, when a feed with a digestion rate of 0.04 has passage rate changed from 0.04 to 0.08, ruminal escape will increase from 50

to 67% (17 units or 34%). The same passage rate change for material with digestion rate of 0.10 increases escape from 29 to 44% (15 units or 52%). Increased intake of a nutrient may not always increase the extent of escape, however, as the microbial population in the rumen can adapt to specific sources of energy and nutrients. When feed intakes are high, time for fermentation becomes a more prominent limit to the extent of microbial fermentation. The elevated rate of passage results in decreased extent of ruminal digestion, but will permit feed intake to increase (Owens and Goetsch, 1986).

Increased intake does not usually reduce digestibility of forages fed in the long form, probably because of lengthy rumen retention of the forage particles. In contrast, total tract digestibility generally decreases when intake of a concentrate diet increases (Reid *et al.*, 1980). In addition to direct effects of level of feed intake on ruminal retention time, high feed intakes may reduce the degree of mastication and rumination as well as ruminal pH, the latter causing reduced digestion rate.

When feed intake increases, ruminal digestion is usually depressed more than total tract digestion because digestion in the small intestine (for concentrate feeds) and fermentation in the large intestine (for concentrates and forages) can partially compensate. The degree of compensation is limited by particle size and flow rate (Orskov, 1982) and conditions for post-ruminal digestion (Owens *et al.*, 1984).

Frequent feeding can decrease the lag time for digestion and should produce more constant flow rates to the small intestine (Grovum and Williams, 1973), which can increase intestinal starch digestion. Frequent feeding to establish steady-state conditions of nutrient outflow should maximise both ruminal digestion and output of microbial N.

2.6.4 ORGANIC MATTER DIGESTION IN THE RUMEN

In a review of results for 28 fresh or frozen grasses fed to sheep, Thomson and Beever (1980) concluded that the proportion of the digestible OM intake apparently digested in the rumen appeared to be unaffected by either forage species or feeding level (mean

value of 0.60). Similarly. with sheep grazing native pastures in Australia, Corbett *et al.* (1982) obtained a value of 0.58. With hay and concentrate mixed diets fed to cattle, Smith *et al.* (1978) also observed values of 0.67, 0.62 and 0.63 for ground nut meal, fish meal and soyabean meal supplements respectively. Veira *et al.* (1980) supplemented 3 levels of soyabean meal to cattle fed on corn and straw base diet, and observed the values of 0.56, 0.53 and 0.59 for the low, medium and high level of soyabean meal supplementation.

2.6.5 PROTEIN DIGESTION (OR DEGRADATION) IN THE RUMEN

The crude protein (N x 6.25) in feeds contains true protein and non-protein nitrogen (NPN). Nitrogen in NPN is present in the form of peptides, free amino acids and their amides, amines, nucleotides, ureides and inorganic nitrogen in varying proportion (Hegarty and Peterson, 1973).

Plant proteins may be divided into leaf proteins and seed proteins. Leaf proteins are almost entirely metabolic proteins (enzymes) concerned with growth and biochemical functions of the leaf cells (Lyttleton, 1973; Mangan, 1982). The seed proteins, on the other hand, constitute part of the reserve material in the seed to be used as a nutritive reserve for the embryo (Lyttleton, 1973).

The true protein content frequently accounts for 75 to 80% of the total crude protein in fresh forage protein (Lyttleton, 1973) and in seed proteins (Ersland *et al.*, 1983; Shewry and Miflin, 1983). The water soluble leaf proteins (up to 50% of the protein), contain two major classes of protein called Fraction 1 and Fraction 2. Fraction 1 leaf protein is a single homogeneous protein while Fraction 2 leaf protein is a complex mixture of many different proteins (Mangan, 1982). The insoluble leaf proteins often account for up to 50% of the protein with a major part associated with the lipid material in the cell membrane structures (Lyttleton, 1973).

The seed proteins, such as in barley seeds, contain 10-20% albumins (soluble in distilled water or dilute salt solutions) and globulins (soluble in dilute salt solutions but not in distilled water), 7-38% glutelins (soluble in dilute acid or alkali), and 30-40% prolamins (soluble only in dilute ethanol)(Shewry and Miflin, 1983). Globulins are the major storage protein in legume seeds and make up about 80% of the total protein content in the seeds (Ersland *et al.*, 1983).

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Since natural feeds contain varying degree of the soluble and insoluble fractions, the degradability (rumen digestibility) of feed protein is also variable between individual feeds. The feeds that contain a large proportion of soluble protein fraction are often degraded to a greater extent than those contain less soluble fraction (Lindberg, 1985). However, soluble proteins such as serum albumin, oval albumin, chloroplast protein extract and soluble proteins from soyabean meal and rapeseed meal have variable resistance to degradation in the rumen (Mahadevan *et al.*, 1980).

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Lindberg (1981) suggested that part of the nitrogenous compounds in many natural feeding stuffs are protected from degradation by a fibrous structure. Consequently, before the insoluble nitrogen fraction can be potentially available for degradation, the fibrous structure has to be broken down by rumen microorganisms. Although this may be most pronounced for roughage (Lindberg and Varvikko, 1982), the degradation of insoluble nitrogen was also negatively correlated to the content of fibre (neutral detergent fibre) in the oilseed cakes (Tamminga, 1983).

Most feedingstuffs have to be treated in one way or another in order to preserve them over the feeding period. During dehydration (drying or wilting) of the crop plant, proteins are degraded by plant enzymes to peptides, free amino acids and amides. The extent of proteolysis is influenced by the water content of the crop, presence of oxygen and pH (McDonald, 1982). When the crop is ensiled the proteolysis is often more extensive than during drying owing to the high water content.

Treatment of the feed proteins with heat, tannins or aldehydes can drastically change the solubility of the proteins and their susceptibility to hydrolysis by enzymes (Ferguson, 1975). Treatment of feed proteins with formaldehyde, for example, can protect part of proteins from degradation in the rumen (Chalupa, 1975).

There can be wide variation in protein degradation within and among feedstuffs, as well as significant differences among animals with regard to rumen environment and retention time of feed in the rumen. The rate and extent of degradation of a protein are likely to be influenced by its solubility. Soluble protein is thought to be very rapidly degraded in the rumen, but the insoluble fractions are more slowly degraded, at different rates. Not only the rate of degradation, but also the rate of passage, which is influenced by the level of feed intake, affects the actual extent of protein degradation in the rumen (Orskov and McDonald, 1979; Tamminga *et al.*, 1979).

The extent to which protein is degraded in the rumen will depend upon microbial proteolytic activity in the rumen, microbial access to the protein, and rumen turnover. Differences in the proteolytic potential of rumen digestion under a variety of feeding conditions have been small. Microbial access to the protein seems to be the most important factor influencing protein degradation in the rumen.

Retention time of feed protein in the rumen can influence protein degradation. Proteins retained for a short time are degraded to a lesser extent than those with a longer retention time. Retention time is influenced by particle size of the feed (Balch and Campling, 1965) and by the quantity of the feed eaten (Balch and Campling, 1965; Zinn *et al.*, 1981; Lindberg, 1982). The amount of undegraded protein in lactating cows eating either 8.2 or 12.3 kgDM daily was 29 and 45% respectively (Tamminga *et al.*, 1979). High producing ruminants consuming large quantities of feed are likely to have a larger percentage of undegraded protein than animals consuming low or moderate amounts of feed. The effect of level of intake on retention time of feed particles, however, is sometimes quite small (Hartnell and Satter, 1979), and the impact on protein degradation may often be minor (Miller, 1973) or non-existent (McAllan and Smith, 1983).

2.6.6 EFFECT OF RUMEN AMMONIA CONCENTRATION ON RUMINAL DIGESTION

A large proportion of the N requirements of rumen microbes for protein synthesis may be met from the rumen ammonia pool. These requirements are often expressed in the form of concentration in the rumen required for maximum growth or activity. Optimum concentrations found to sustain maximum bacterial activity and microbial protein synthesis have been variously reported to range from 6 to 90 mgNH_3-N/litre (Schaeffer *et al.*, 1980; Satter and Roffler, 1975; Pisulewski *et al.*, 1980) although many of these value were determined *in vitro* where requirements may be lower than *in vivo*.
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However, other authors have reported that higher concentrations of rumen ammonia were required to achieve maximum microbial protein or NAN flow at the duodenum to range from 90 to 240 mgNH_3-N/litre (Allen and Miller, 1976; Satter and Slyter, 1974; Hume *et al.*, 1970). Hume *et al.* (1970) reported that the maximum concentration of microbial protein in the rumen corresponded with an ammonia concentration of 90 mgNH_3-N/litre, but more importantly, the flow of microbial protein from the rumen was greatest with an ammonia concentration of 130 mgNH_3-N/litre. Allen and Miller (1976) found that NAN flow through the abomasum increased linearly with increased intake of nitrogen in the form of urea and the greatest flows occurred when ammonia concentrations in the rumen were 160 and 220 mgNH_3-N/litre. Recent studies have clearly shown that for cattle fed low N - low digestibility forage, the minimum level of rumen ammonia concentration for optimum intake is approximately 200 mgNH_3-N/litre (Krebs and Leng, 1984; Boniface *et al.*, 1986; Perdok *et al.*, 1988). These results are similar to those of Mehrez *et al.* (1977) which indicated that the disappearance of DM from polyester bags suspended in the rumen was maximised when the rumen concentration of ammonia was 230 mgNH_3-N/litre.

Urea supplementation to low quality (low protein and low digestibility) feed has been reported to increase rumen ammonia concentration, increase digestibility of forage and increase forage DM intake (Krebs and Leng, 1984; Boniface *et al.*, 1986; Perdok *et al.*, 1988), probably because of the consequent increase in rumen ammonia concentration.

2.6.7 EFFECT OF THERMAL ENVIRONMENT ON DIGESTION

Ruminants are homeothermic animals and they attempt to maintain a constant deep body temperature (approximately 37°C). As temperatures increase, ruminants will attempt to reduce heat production by reducing energy or food intake (Young, 1987). The reduced food intake may cause a reduction in rumen motility. During exposure to hot environment, animals' metabolism is reduced and this was found to be associated with a reduction in thyroid secretion and an increase in gut fill (Miller *et al.*, 1974; Fuquay, 1981). Miller *et al.* (1974) proposed that reduced gut motility resulting from low thyroid output in heat exposed cattle could permit accumulation of material in the rumen. In addition, Lippke (1975) also suggested that thyroid activity, through its influence on rate of passage, is an important mediating factor in the effects of heat stress on voluntary food intake and digestibility.

When ruminants are exposed to hot conditions, they attempt to increase their rate of evaporative heat losses, with consequent increases in water requirement (McDowell *et al.*, 1969; Bhattacharya and Uwayjan, 1975). Increases in water consumption have been reported not to affect rumen metabolism (More *et al.*, 1983).

Earlier published reports have shown a positive relationship between environmental temperature and energy digestion in sheep (Graham *et al.*, 1959) and in steers (Blaxter and Wainman, 1961). However, there have also been several conflicting reports and some of these might be attributed to a confounding temperature treatments with variations in feed intake (Bhattacharya and Hussain, 1974; Guerrini, 1981). With cattle on roughage-based rations, increases in digestibility with increasing temperature (from 20 to 33-40°C) have been reported (Colditz and Kellaway, 1972; McDowell *et al.*, 1969). However, no effect of increasing temperature (from 20 to 30°C) in sheep fed a pelleted barley-alfalfa diet on digestibility was observed by Young and Degen (1981). The digestibility of forage-based diets which tend to be fermented slowly appears to be more susceptible to temperature induced changes in motility and passage rate of digesta (Christopherson and Kennedy, 1983). Kennedy *et al.* (1982) also suggested that digestibility of a rapidly fermented concentrate diet in sheep was unaffected by temperature. Similarly, William and Innes (1982) with young calves fed a milk replacer diet and McBride (1982) (quoted by Christopherson and Kennedy, 1983) with

lambs fed an all-concentrate diet also reported no effect of temperature on diet digestibility. With a mixed hay:concentrate of 25:75, 50:50 and 75:25 diet fed to sheep, Bhattacharya and Uwayjan (1975) reported no effect of temperature on digestibilities of DM, CP and energy.

2.7 MEASUREMENT OF PROTEIN DEGRADABILITY

Protein degradability can be estimated by *in vitro, in vivo* and *in sacco* methods. *In vivo* measurements are associated with surgically operated animal, intensive labour, time consuming and large expenses. Although several *in vitro* methods have been proposed (Broderick, 1982) most interest during recent years has focused on the *in sacco* technique. The main emphasis in this review will be on estimates obtained with the *in sacco* technique. However, other procedures are also discussed.

2.7.1 *IN VIVO* METHOD

In vivo measurements of feed protein degradability usually require the use of surgically prepared animals equipped with either simple or re-entrant cannulae in the rumen and abomasum or duodenum (Miller, 1982; Lindberg, 1985).

Determination of digesta flow with a re-entrant cannula may be accompanied with total collection of the ingesta, or more commonly by use of an indigestible digesta marker and collection of spot samples (Zinn *et al.*, 1980). When using animals prepared with T-type cannula, spot samples are taken and flow rate of digesta is calculated by reference to digesta markers. It is also necessary to use reliable markers to calculate the flow of digesta and of microbial protein.

The amount of undegradable protein can be estimated as the difference between protein intake,and the sum of endogenous and microbial protein entering the abomasum or small intestine. Procedures for estimating microbial protein are available, utilising microbial markers such as nucleic acids, diaminopimelic acid

(DAPA), aminoethylenephosphoric acid (AEP), or one of the radioisotopes, ^{35}N, ^{32}P, or ^{15}N (Clark, 1977).

Despite the difficulties of measuring protein degradation *in vivo*, *in vivo* measurements are essential, for they serve as the standard against which all chemical or *in vitro* methods for estimating protein degradation must be evaluated (Lindberg, 1985; NRC, 1985).

2.7.2 *IN VITRO* METHOD

2.7.2.1 Solubility

The principle of these determinations is an extraction of the soluble nitrogen components in the feed with a solvent for a set period of time. A large number of solvents have been used to estimate the solubility such as McDougal's mineral buffer (Crooker *et al.*, 1978), Burroughs mineral buffer (Burroughs *et al.*, 1950; Wohlt *et al.*, 1973; Crooker *et al.*, 1978; Crawford *et al.*, 1978), Durand's buffer (Lindberg *et al.*, 1982), sodium chloride (Smith *et al.*, 1959; Little *et al.*, 1963) and distilled water (Little *et al.*, 1963).

The solubility can be influenced by various factors associated with the solvent (e.g. pH, ionic strength) and the extraction procedure (e.g. temperature, extraction time, degree of agitation, sample particle size). Examples of differences between various solvents are given by Wohlt *et al.* (1973), Crawford *et al.* (1978) and Vencl (1983).

Several reports showed that the buffer-solubility of feeds is often closely related to short-term rumen degradability *in sacco* (Nocek *et al.*, 1979; Lindberg *et al.*, 1982; Stern and Satter, 1984) and also that the correlation progressively decreases with increasing incubation time *in sacco* (Stern and Satter, 1984). There appears to be poor agreement between buffer-solubility and effective rumen degradability of protein across feed components but within the same class of feed it could be a feasible and simple way of obtaining estimates of degradability (Lindberg, 1985).

Stern and Satter (1982) evaluated the relationship between N solubility in Burroughs mineral buffer, N disappearance from dacron bags, and *in vivo* measurements of degraded intake protein for 34 total mixed diets containing various dietary N sources. They found that N solubility was highly correlated with N disappearance from bags in the rumen for short exposure times, but as exposure time increased the correlation between these procedures progressively decreased. The correlation between N solubility and degradation of protein *in vivo* was poor (0.26), indicating that solubility may be a poor predictor of protein degradation.

2.7.2.2 End-product Accumulation

Measurements of the amount of ammonia produced *in vitro* from a feed incubated with rumen liquor have been suggested as one way of obtaining estimates of protein degradation (Chamberlain and Thomas, 1979).

The agreement between ammonia concentration *in vivo* and *in vitro* depends on the incubation period used *in vitro*. A comparable description of the feed protein metabolism *in vivo* was obtained at 4 h *in vitro* incubations (den Braver, 1980 quoted by Lindberg, 1985).

The estimates obtained will be affected by the relation between fermentable carbohydrates and nitrogen in the feed and their rate of degradation. In feeds containing large amounts of readily fermentable carbohydrates a considerable amount of ammonia is used for microbial growth (Broderick, 1978; Chamberlain and Thomas, 1979) and will lead to an underestimation of the true degradation. The ammonia production values therefore give the net result for the balance between feed nitrogen degraded and the microbial protein production possible rather than a true protein degradation value.

Broderick (1978) developed a system for *in vitro* determinations of the protein degradation from the end-product accumulation in the presence of hydrazine (inhibits amino acid deamination and ammonia uptake) whereby description of protein degradation as a first-order process enabled estimates to be made of ruminal escape of

casein. The system has recently been applied also to typical ruminant feeds (Broderick, 1984).

2.7.2.3 Continuous Fermentation

The development of continuous culture systems for studies of rumen fermentation (Merry *et al.*, 1983) provides an interesting alternative way of obtaining estimates of protein degradation. In these systems, solid feed can be added continuously at variable rates and the turnover of solid and fluid in the vessel may be varied independently. Merry *et al.* (1983) obtained good agreement between the continuous culture parameters and *in vivo* measurements.

2.7.2.4 Proteolytic Enzymes

The use of various proteolytic enzymes to estimate feed protein solubility or insolubility has attracted great interest during recent years. Poos *et al.* (1980) compared estimates of insolubility in 0.15 M sodium chloride, 0.02 N sodium hydroxide and hot water and nitrogen disappearance *in sacco* (at 1, 4, 6, 8, 12 and 24 h) with animal performance data on beef cattle on 9 diets. They found that disappearance with the fungal proteases was most closely related to animal performance data.

Pichard and Van Soest (1977) suggested the use of a protease from *Streptomyces griseus* to predict rate of feed protein degradation. It was recently shown by Krishnamoorthy *et al.* (1982) that *in vitro* proteolysis with a protease from *Streptomyces griseus* was significantly ($p<0.01$) related to *in vivo* degradation of alfalfa hay and corn silage diets ($n = 12$, $r = 0.84$). An incubation time of 18 h was suggested for grain mixtures and 48 h for hay and silage.

It appears that the *in vitro* procedures with the greatest potential to be an alternative to or to replace the *in sacco* method are the continuous fermentation systems and the proteolytic enzymes. However, more research is needed in this field of study.

2.7.3 *IN SACCO* METHOD

While the use of cannulated animals can provide estimates of protein degradation in the rumen, *in vivo* estimates are labour intensive and time consuming. Alternative techniques that can provide rapid, yet reasonable estimates of protein degradation for a wide variety of feedstuffs are desirable. One of the promising approaches is the *in sacco* or nylon bag technique. Mehrez and Orskov (1977) suggested that this *in sacco* technique is suitable for determination of protein degradation.

The simplest application is to suspend the porous bags within the rumen in a normal rumen environment for an arbitrary period of time, thus give a relative estimate of protein degradation. Alternatively, the extent of protein degradation can be determined at the moment when a predetermined percentage of the truly digestible organic matter has disappeared from the bag, thus simulating the extent of degradation in the rumen of normally fed animals (Orskov and Mehrez, 1979). In other words, the extent of protein degradation was assumed to be equal to the proportion of N disappearing from the bag at that time when 90% of the digestible DM had disappeared from the bag (Mathers and Miller, 1981). However, ruminal retention time and ruminal OM digestion vary among diets, intake levels and many other conditions.

Several methods have been used to combine *in sacco* N disappearance and ruminal dilution rate information (Orskov and McDonald, 1979; Mathers and Miller, 1981). These methods used rate constants for both nitrogen disappearance and passage rate. Details of *in sacco*, also called *in situ*, procedures have been extensively reviewed by Lindberg (1985).

2.7.4 FACTORS AFFECTING DETERMINATION OF RUMINAL PROTEIN DEGRADABILITY BY NYLON BAG TECHNIQUE

A number of factors can have an influence on the protein degradability values obtained. These include bag pore size (Mathers *et al.*, 1977; Weakley *et al.*, 1983), sample particle size (Mohamed and Smith, 1977), sample size and bag size (Mehrez and Orskov, 1977), time of incubation in the rumen (Orskov *et al.*, 1980), animal species (Lindberg, 1985), microbial nitrogen in bag residues (Mathers and Aitchison, 1981), the basal diet of the cannulated animal (Ganev *et al.*, 1979; Lindberg, 1981a), and the rate of outflow from the rumen of unfermented feed particles (Mehrez and Orskov, 1977; Orskov *et al.*, 1980; Orskov *et al.*, 1983). Of these factors, the most important influencing the degradability estimates of feedstuffs for ruminants, are the animal's basal diet and the fractional outflow rate of undigested feed particles.

2.7.4.1 Animal's Basal Diet

Factors affecting the rumen microflora will probably have an influence on measurements of rumen degradability by the nylon bag technique. Changing the basal diet from a high roughage to a high cereal content has often been found to have a negative influence on protein degradability (Lindberg, 1985). Ganev *et al.* (1979), for example, observed that the degradabilities of protein in the bags was lower (by 6 to 10%) when the sheep were fed a diet based on barley compared to a diet based on dried grass. The degradabilities obtained in Denmark by using a hay-fed cow and a passage rate of 0.08/h are almost equivalent to the degradabilities obtained in Sweden using cows fed a mixed ration composed of 50% concentrate and 50% hay and a passage rate of 0.05/h (Linberg, 1985). However, not only the proportion of roughage to concentrate in the diet, but also the concentrate carbohydrate composition has to be considered. One of the main reasons for negative effects on protein degradation of a change in carbohydrate sources and composition appears to be an effect on rumen pH (Mould and Orskov, 1983). Level and source of nitrogen are both factors of importance for an active rumen microflora and can influence the degradability values (Lindberg, 1985).

2.7.4.2 Fractional Outflow Rate of Feed Particles

The level of feeding can have an influence on the outflow rate. Rates of protein degradation may be lower when the diets are fed *ad libitum* than when they are given as restricted feeding, because of the enhanced rate of passage from the rumen. Orskov *et al.* (1980) observed that degradability decreased with increasing flow rates from the rumen, therefore the ruminal passage rates have an effect on the degradation of proteins.

It has been reported that the solid outflow rates of various protein sources were usually in the range of 0.04 and 0.06 per hour (Lindberg, 1982; Stern and Satter, 1982) and were quite constant at a common feeding level (Lindberg, 1982). Orskov and McDonald (1979) have suggested the value of 0.046/h at restricted feeding and 0.060/h at *ad bilitum* feeding. The values of 0.03-0.07 have also been reported for whole barley grain-fed sheep by Ganev *et al.* (1979) and Mehrez *et al.* (1980). The Feed Evaluation Unit of the UK Agricultural Development and Advisory Service has now published tables, from nylon bag measurements, of degradabilities at three values of fractional outflow rates (k); 0.02 for cattle and sheep given completely ground diets or a very low feeding level of a mixed diet; 0.05 for calves, low yielding dairy cows, beef cattle and sheep given a high level of mixed diets; 0.08 for high yielding dairy cows (fed at more than twice maintenance) given mixed diets; for a variety of feeds (ADAS, 1989).

2.7.4.3 Other Factors

The choice of pore size of the bag cloth must be a compromise between the risk of losing undegraded feed particles, the extent of inflow of solid rumen contents and the limitation of liquid inflow and outflow (Lindberg, 1987). The presence of pores in the material is necessary to allow rumen micro-organisms to gain access to the feed. Excessively fine material would definitely prevent entry of certain of the larger protozoa and possibly cause clogging of the pores owing to micro-colony formation on

the material, while excessively large pores might allow loss of digested sample material or permit entry of the surrounding ingesta into the bag.

The choice of a suitable sample particle size is closely linked to the bag pore size used (Lindberg, 1985). In bags with fine pores (i.e. 10 μm) the effect of particle size can be seen at long (24 hours) but not at short (2 to 6 hours) incubation times (Lindberg, 1981). If, on the other hand, the pore size is increased (>50 μm) the effect of particle size is most pronounced at short incubation times (Freer and Dove, 1984). This is most likely due to differences in the inflow of liquid and microbes in bags of different pore sizes (Lindberg *et al.*, 1984).

2.8 SCOPE AND OBJECTIVES OF THE PRESENT STUDY

Little information is available about the effects of supplementation with concentrates which differ in protein characteristics on the performance of dairy cows fed on tropical forages in Thailand.

Therefore a series of five experiments related to this subject was carried out. In the first experiment, cows fed on fresh tropical forage (grazed and cut) were given two levels and two types of supplements which differed in protein characteristics. In the second experiment, cows fed on silage made from tropical forage were given supplements containing the same protein concentration but differing in protein degradability (by inclusion of urea).

In the third experiment, measurements were made *in sacco* of the protein degradability for 10 feedstuffs which are commonly used in Thailand.

In the fourth experiment, the effects of hot climatic conditions and dietary protein on rumen nitrogen metabolism was measured in sheep fed on low quality hay, in New Zealand.

A final experiment measured the effects of a supplement, with high concentration of low degradable protein, on milk production by cows grazing on winter pasture in New Zealand.

In addition, a feed planning exercise is also included. This is to quantify two dairying systems (monthly and seasonal calving) in Thailand by applying some of the present experimental data into the two systems.

CHAPTER 3

GENERAL MATERIALS AND METHODS

3 GENERAL MATERIALS AND METHODS

3.1 ENVIRONMENT

A series of trials presented in this study was conducted between May 1990 and December 1992, at various sites of experiment. These included the Dairy Farming Promotion Organisation of Thailand, Muak Lek, Saraburi and Khon Kaen University, Khon Kaen, Thailand; the Massey No.1 Dairy Farm and Massey Dairy Cattle Research Unit, Massey University, Palmerston North, New Zealand. Specific details of each site of experiment are therefore given in each chapter and in Appendices 2.1, 2.2 and 2.3.

3.2 METEOROLOGICAL DATA

As the trials varied from place to place and from time to time, meteorological data of each trial and each period are separately given in each chapter and in Appendix 1.

3.3 ANIMAL AND FEED MANAGEMENT

The management of both animals and feeds varied from trial to trial. Specific management details are therefore given in each chapter.

3.4 ANIMAL AND FEED MEASUREMENTS

The type and frequency of measurements made in each trial are presented in the appropriate chapters. The details of the techniques and equipments used to make each measurement are presented in Appendix 3.

3.5 STATISTICAL ANALYSES

All data were analysed using a general linear model procedure by Statistical Analysis System (SAS).

Feed Intake Measurements

The data on the intakes of dry matter, total dry matter, metabolisable energy, total metabolisable energy, crude protein and total crude protein in Chapters 4, 5, and 8 were subject to univariate analysis of variance according to the model in Appendix 4.1.

The data on intakes of feed DM and water in Chapter 7 were subject to analysis of variance in Latin Square according to the model in Appendix 4.4.

Animal Performance

The data on yields of milk, milk fat milk protein and milk lactose; concentrations of milk fat milk protein and milk lactose in Chapters 4, 5 and 8 were subject to repeated measurement analysis of covariance according to the model in Appendix 4.3.

The data on liveweight and condition score change were subject to univariate analysis of variance according to the model in Appendix 4.1.

The data on final liveweight and condition score were subject to analysis of covariance according to the model in Appendix 4.2.

In Chapter 7, the data on degradation and digestibility of feeds were subject to analysis of variance in Latin Square according to the model in Appendix 4.4.

The data on rumen pH, rumen ammonia concentration and concentration and molar proportion of VFA in Chapter 7 were subject to multivariate analysis of covariance in Latin Square according to the model in Appendix 4.5.

CHAPTER 4

THE EFFECT OF CONCENTRATE LEVEL AND TYPE OF PROTEIN ON DAIRY COW PERFORMANCE IN EARLY LACTATION FED ON FRESH TROPICAL PASTURE

4.1 INTRODUCTION AND OBJECTIVES

Productivity of cattle fed solely on tropical pastures is usually lower than that of cattle fed temperate pastures (Walker, 1987). This lower production is mainly caused by the poorer feeding value (digestibility and crude protein concentration) of the tropical pastures since relatively high levels of animal production can be achieved in the tropics if grain supplements are fed (Stobbs, 1971; Royal and Jeffrey, 1972; Minson, 1982). Tropical pastures are low in digestibility and nitrogen concentration (Hamilton *et al.*, 1970), so supplementary feeding, particularly with energy and protein supplements, would be expected to result in substantial increases in nutrient intake and thus in animal production.

In a review of supplementary feeding of concentrates to dairy cattle grazing on temperate pastures it was concluded that given ample pasture availability, responses in milk yield would be small and uneconomical (Leaver *et al.*,1968). Responses of 0.32 and 0.40 kg milk/kgDM supplement were reported by Leaver *et al.* (1968) and Journet and Demarquilly (1979) respectively. Rogers (1985) reviewed 4 experiments where cows were fed pasture and supplemented with protein-rich or energy-rich concentrates. In two experiments cows fed pasture to appetite had modest increase in milk yield when given protein-rich concentrates (the responses ranged from 0.35 to 0.48 kg milk/kgDM supplement). By comparison the responses to energy-rich concentrates were even smaller ranging from -0.2 to 0.26 kg milk/kgDM supplement. In a third experiment when cows were restricted on pasture the response to a protein-rich supplement was significantly higher than to an energy-rich supplement (milk yields were respectively 23.0 and 19.4 kg when 4 kgDM supplement from either protein-rich or energy-rich concentrates were fed).

With tropical pastures, Jennings and Holmes (1985) reviewed 11 short term trials varying in type and amounts of supplements, and in the duration of feeding, and concluded that response in milk yield to 1 kgDM supplement consumed averaged 0.47 kg milk. When types of concentrate were taken into account, the response to energy-rich supplement, such as grain or molasses, was similar to the response from balanced concentrates (0.52 and 0.40 kg milk/kg supplement respectively) whereas the response to a protein-rich supplement was considerably higher (0.82 kg milk/kg supplement,

See Section 2.3.2, Chapter 2). In these, the intake of pasture DM by cows on protein-rich supplement was higher than the pasture DM intake by cows on energy-rich supplement. It would appear that the feeding of protein-rich supplements resulted in a higher intake of pasture than when feeding energy-rich supplements leading to higher total ME intakes and hence productivity from the former supplements.

In contrast to the above evidence some authors reported that energy supplements produced larger responses than protein supplements. For example, Royal and Jeffrey (1972) compared the effects of either a protein-rich or energy-rich supplement, or a combination of both, given to cows grazing Kikuyu dominant pastures. They recorded a significant linear correlation between the dry matter intake of the supplement and milk production, and concluded that milk production was limited more by energy than protein supply. However, other authors have shown that when cows were fed protein sources of low solubility (Davison *et al.*,1982) or low rumen-degradability (Stobbs *et al.*,1977; Flores *et al.*,1979), the responses to additional protein were more evident.

Stobbs *et al.* (1977) obtained a 20% increase in milk yield (2.4 kg milk/kg supplement) when cows grazing tropical pastures were supplemented with 1 kgDM protected casein. Davison *et al.* (1990) recorded a 9% increase in milk yield (1.6 kg milk/kg supplement) to cows fed meat-and-bone meal in early lactation while grazing tropical grass pastures. The trial by Stobbs *et al.* (1977), in particular, showed very large response, greater in fact than could have been expected from the energy supplied by the supplement alone.

In view of the lack of consistency in the above published evidence, and the need for information of relevance to Thailand, the present study was designed to determine the effects of two alternative protein supplements on animal performance. The present investigation, consisting of an indoor feeding and a grazing experiment, was designed to measure the effects of two supplements (containing protein of high or low degradability) fed at two levels, on milk production by cows fed on tropical pasture. Effects on herbage intake, yields and composition of milk and liveweight change were also examined.

Protein supplements with different degradabilities were used because many published reports have suggested higher responses from supplements with protein of low degradability (including the experiment in New Zealand, Chapter 8). High degradability protein supplements (by inclusion of urea) are commonly used in Thailand. The choice of a large difference in crude protein concentration (17% and 30% CP) was because the 30% supplement was used in the New Zealand experiment (Chapter 8) while the 17% CP supplement is commonly used in Thailand and this was expected to give a wide range of RDP and UDP intake from the supplements. Two levels of supplement feeding (3 and 6 kg/cow daily) were chosen because the low level (3 kg/cow daily) was used in the New Zealand experiment and the high level (6 kg/cow daily) is normally fed to dairy cows in Thailand.

4.2 INDOOR EXPERIMENT

4.2.1 PRE-EXPERIMENTAL CONDITIONS

The investigation was conducted at the Dairy Farming Promotion Organisation of Thailand, Muaklek, Saraburi, Thailand for 7 weeks (8 Oct.- 26 Nov.1990). Climatological data and background data for the experimental site are given in Appendices 1.1 and 2.1.

4.2.2 MATERIALS AND METHODS

4.2.2.1 Animals and Treatments

Forty crossbred dairy cows (62.5-75% Holstein Friesian or Red Danish crossed with local *Bos indicus* breed), in their first 3 months of lactation were randomly allocated into 5 treatment groups of 8 cows each, and details of treatments are presented below.

Treatment 1.	PF	- Pasture only.
Treatment 2.	17PL	- Pasture plus 3 kg of 17%CP (locally used; high degradable protein) concentrate.
Treatment 3.	17PH	- Pasture plus 6 kg of 17%CP (locally used; high degradable protein) concentrate.
Treatment 4.	30PL	- Pasture plus 3 kg of 30%CP (low-degradable protein) concentrate.
Treatment 5.	30PH	- Pasture plus 6 kg of 30%CP (low-degradable protein) concentrate.

The cows were housed in individual stalls, and given freshly cut pasture herbage which was cut by a double-chopped harvester.

Forty cows were selected, from 66 available, following the measurement of milk yields over 4 consecutive days (pre-experimental period in Section 4.2.2.2). They were allocated to the five treatment groups. Mean data for cows at the start of the experiment (over 4 days) are given in Table 4.2.1.

Table 4.2.1 Data for cows at the start of the experiment.

Mean values for:	PF	17PL	17PH	30PL	30PH	Sig.
No. of cows	8	8	8	8	8	-
Days in milk	45	42	48	47	50	NS
Milk yield (kg/cow daily)	12.4	12.6	12.4	11.6	11.5	NS
Fat yield (kg/cow daily)	0.54	0.55	0.56	0.54	0.48	NS
SNF yield (kg/cow daily)	1.05	1.07	1.05	0.98	0.98	-
Fat concentration (%)	4.35	4.38	4.48	4.71	4.49	NS
SNF concentration (%)	8.45	8.48	8.47	8.42	8.51	-
Liveweight (kg)	368	385	396	377	364	NS

4.2.2.2 Animal and Feed Management

An outline of the programme is summarised as follows:-

Indoor Experiment	
Preexperimental period	- Before the start of the experiment, all cows were grazed as one group and were offered a daily allowance of approximately 20 kg of herbage dry matter (pasture availability being measured above approximately 15 cm cutting height). They were supplemented with a locally used concentrate and fed according to their milk yield at the rate of 0.5 kg concentrate per 1 kg milk. Sixty six cows were then housed and fed cut pasture and the locally used concentrates. Milk yields were recorded on 4 consecutive days to select the balanced groups of experimental animals.
Week 1-2 (Preliminary period)	- All cows (8 cows/treatment) were individually fed indoors and offered cut pasture *ad libitum* twice daily (0700am and 0430pm) after milking. At this time the 2 types and 2 levels of concentrates were introduced to the supplemented cows according to their treatment groups twice daily (0530am and 0300pm) before milking.
Week 3-6 (Experimental period)	- The Experimental Period I: the cows were fed *ad libitum* cut pasture. Concentrates were fed to the supplemented cows according to their treatment group. Milk yield was recorded daily, milk fat twice per week (consecutive days) and liveweight weekly.

Grazing Experiment (continued with the three groups PF, 17PH and 30PL)

Week 7 (Preliminary period)	- All cows were turned out to pasture and grazed as one group, and allowed approximately 20 kg of herbage dry matter/cow daily, measured at 15 cm above ground level, for 4 days. They were then grazed separately in the three treatment groups (PF, 17PH and 30PL) at the same common allowance on pasture averaging 2,490 kgDM/ha pregrazing herbage mass (HM) for a further 3 days and fed the appropriate concentrates according to treatment for a further 3 days pre-experimental period.
Week 8-9 (Experimental period)	- Three groups of cows (PF, 17PH and 30PL) were grazed separately at an allowance of approximately 25 kg of herbage dry matter/cow daily and fed concentrates according to treatments. Milk yield, milk fat and liveweight were recorded as stated above.

4.2.2.3 Pastures and Supplements

The pastures used were mainly Guinea grass (*Panicum maximum*) with small amounts of Centro (*Centrosema pubescence*), and Ruzi grass (*Brachiaria ruziziensis*) receiving approximately 300 kg/ha 15-15-15 N:P:K annually and an approximate monthly (for 6-7 months of rainy season) application of 156 kg/ha of urea.

The concentrates comprised mainly local feedstuffs (See Table 4.2.2). The difference between the two concentrates was mainly in protein degradability. The locally used concentrate, which was the same as that used during the pre-experimental period, contained protein of high degradability mainly because of the inclusion of 2% urea whereas the high protein meal was formulated to be of low protein degradability using values obtained from the literature. Details of the ingredients used in the concentrates are given in Table 4.2.2.

Table 4.2.2 The formulation of concentrates used (per 1000 kg).

kg

Ingredients	17% CP High Degradability	30% CP Low Degradability
Canola (rape seed meal)	50	-
Cassava (tapioca)	290	-
Coconut meal	120	135
Cotton seed meal	150	290
Kapok seed meal	10	-
Maize	80	195
Minerals	30	30
Molasses	80	-
Palm seed meal	180	100
Peanut meal	150	-
Rice bran	40	-
Soybean meal	-	250
Urea	20	-

4.2.3 MEASUREMENTS

Unless otherwise stated, the methods and equipment used to make the measurements described below are those detailed in Appendix 3.

4.2.3.1 Feed Measurements

The weight of herbage offered to each cow and left uneaten by each cow in the indoor experiment were weighed twice daily at feeding time. Duplicate samples of herbage were taken twice daily before and after feeding throughout the experimental period and

then dried at 80°C for 36 hours. This enabled herbage DM intake each day to be calculated. A subsample of dried herbage bulked each week was ground through a 1-mm sieve and analysed for N concentration (%, Kjeldahl) and *in vitro* digestibility (%, Roughan and Holland, 1977).

Samples of each type of concentrate used were taken from each batch as it was mixed. A representative subsample was taken for chemical analysis.

4.2.3.2 Animal Measurements

Over the total experimental periods of 7 weeks, individual morning and evening milk yields were recorded daily. Aliquot milk samples were taken on two consecutive days weekly to analyse for fat concentration using Milko tester MK III (Foss electric, Denmark). Unfortunately, the only four Milko scans (Foss electric, Denmark) in Thailand were all out of order therefore protein and lactose concentration could not be analysed. However, milk yields from each cow in each group were bulked at each milking on two consecutive days weekly, and on the same days as for fat analyses, milk samples were taken for SNF analyses (%Total solids - %Fat) See Appendix 3.1.1.

Liveweights were taken on 2 consecutive days and immediately after morning milking prior to the start of the experiment and at weekly intervals throughout.

4.2.4 STATISTICAL ANALYSIS

All data were analysed using the Statistic Analysis System (SAS) computing package (SAS Institute Inc., Cary, NC 27512-8000, USA. 1985,86,87)

Milk yield, fat yield and fat concentration were subjected to multivariate analysis in the sense that the variables were measured at different times on the same individuals. Repeated measurements of covariance using the preexperimental yield and composition data as covariates were taken in order to account for the different error

structure that existed within and between animals across measurement periods (Gill and Hafs, 1971; Morrison, 1976; Bryant and Gillings, 1985). The null hypothesis that the treatment effects were similar was tested within each time period. See Appendix 4.3.

Herbage intake (indoor experiment) and liveweight changes were analysed using analysis of variance (Steel and Torrie, 1986). See Appendix 4.1.

Final liveweight was analysed using analysis of covariance (Steel and Torrie, 1986) using preexperimental liveweight as covariate. See Appendix 4.2.

Treatment effects were considered to be different if the level of significance was less than 5% ($p<0.05$). Where significant differences between treatments existed, tests for differences between means were made using the criterion of least significant difference (LSD) for univariate data, while the criterion of orthogonal contrasts were used in the case of multivariate data.

The symbols *, ** and *** were used throughout to indicate the significance levels of $p<0.05$, $p<0.01$ and $p<0.001$ respectively. Where $p>0.05$, the term NS (not significant) was used. Where significant differences between treatments existed, and the number of treatments was greater than two, means followed by dissimilar letters were different at $p<0.05$.

Relationships between performance and ration attributes (MEI, RDP and UDP) were examined using stepwise multiple regression analyses after covariance adjustment, using the data from individual cows. A variable was only included in a regression if it added significantly ($p<0.05$) to the model.

4.2.5 RESULTS

4.2.5.1 Chemical Analysis of the Feeds

The chemical composition of the concentrates presented in Table 4.2.3 shows that they differed considerably in protein concentration and degradability. (See Table 4.2.3). The estimates of metabolisable energy (ME) concentration in the two concentrates however were similar.

Table 4.2.3 The chemical composition of concentrates (DM basis).

Details:	17% CP High Degradability	30% CP Low Degradability
Dry matter (%)	89.9	90.6
Crude protein (%)	16.9	28.6
Protein degradability (%)[1/]	0.65	0.53
In vitro		
Dry matter digestibility (%)	81.6	80.6
Organic matter digestibility (%)	83.8	82.5
Digestible organic matter in the dry matter (%)	72.2	73.8
Ash (%)	13.8	10.5
Metabolisable energy (MJ/kgDM)[2/]	11.6	11.8

1/ = Estimated from those values reported in Chapter 6.

2/ = ME = 0.16 DOMD (MAFF, 1975).

The chemical analyses of the pastures fed in this experiment are given in Table 4.2.4. The mean value of *in vitro* dry matter digestibility was 61.4 with a relatively low protein concentration due to considerable dead material in the pasture. The value for protein degradability was obtained after 12 h incubation of ground samples (in nylon bags) placed in the rumen of fistulated animals.

Table 4.2.4 Chemical analyses of the pastures.

				in vitro				ME[2/]
	%DM	%CP	dg[1/]	%DMD	%OMD	%DOMD	%ASH	(MJ/ kgDM)
Cut pasture								
Week 1	22.0	11.2	0.43	61.2	60.6	54.6	9.9	8.7
Week 2	23.6	13.6	0.42	63.5	63.8	56.1	12.1	9.0
Week 3	22.4	11.0	0.33	61.3	61.5	54.2	11.8	8.7
Week 4	24.8	11.0	0.39	58.8	59.3	53.2	10.2	8.5
Week 5	25.6	12.6	0.38	60.7	60.5	54.7	9.5	8.8
Week 6	23.4	12.2	0.41	63.1	64.2	58.2	9.3	9.3
MEAN	**23.6**	**11.9**	**0.39**	**61.4**	**61.6**	**55.2**	**10.5**	**8.8**
	(0.6)	(0.4)	(1.3)	(0.7)	(0.8)	(0.7)	(0.5)	(0.1)

1/ = Protein degradability after 12 h incubation (See Chapter 6).

2/ = ME = 0.16DOMD (MAFF, 1975).

Figures in brackets are Standard Error of the Mean.

4.2.5.2 Feed Intake

Feed dry matter (DM), feed metabolisable energy (ME), and crude protein (CP) offered both as pasture and as concentrate as well as total DM, ME and CP offered are shown in Table 4.2.5. The mean intakes in terms of DM, ME, CP for the individual treatment groups are also given in Table 4.2.5.

The unsupplemented cows (PF) consumed significantly more pasture DM ($p<0.001$) than the supplemented groups. Among the supplemented groups, the 17PL cows consumed significantly more pasture DM than the rest ($p<0.05$) while the cows on 17PH concentrate consumed significantly less pasture DM than the others ($p<0.05$). The two groups with the low level of concentrates (2.7 kgDM/cow daily) ate more pasture DM than the two groups with the higher level of concentrates (5.4 kgDM/cow daily), but the effect of level of concentrate feeding on pasture DM intake was significant only at the lower protein level (17PL and 17PH).

The intake of concentrates reduced pasture intake in all treatments but the extent of substitution of concentrate for pasture differed between groups. With the locally used concentrates, an increase in level of concentrate supplementation significantly increased ($p<0.001$) the substitution rate. In contrast, this was not found with the low degradable protein concentrate. In fact, the extra 2.7 kgDM received by the 30PH cows did not cause a significant decrease in pasture intake, compared with the 30PL group, as stated above.

For both concentrates, despite the substitution effect, supplementation increased total DM intake, i.e. the 2 groups receiving the high level of concentrates (5.4 kgDM/cow daily) had the highest total DM intakes.

Both the protein concentration and feeding level of the concentrate significantly increased the total intake of total ME and CP, with the highest intakes being recorded in the cows on the 30PH treatment. Nevertheless, it is interesting to note that the 17PH and 30PH cows had similar ME intakes (156 and 161 MJ/cow daily respectively) but different crude protein intakes (2165 and 2838 g/cow daily respectively) while the 17PH and 30PL cows had a similar crude protein intakes (2165 and 2114 g/cow daily respectively) but different ME intakes (156 and 132 MJ/cow daily respectively).

Table 4.2.5 **Mean values for dry matter (kgDM/cow daily), metabolisable energy (MJ/cow daily) and crude protein (g/cow daily) on offer and eaten by cows.**

	PF	17PL	17PH	30PL	30PH	SEM	Sig.
Dry matter offered							
As pasture	18.4	18.4	18.4	18.4	18.4	-	-
As concentrate	-	2.7	5.4	2.6	5.3	-	-
Total	18.4	21.1	23.8	21.0	23.7	-	-
Dry matter eaten							
As pasture	13.4^{a}	12.7^{b}	10.5^{d}	11.5^{c}	11.1^{c}	0.25	***
As concentrate	-	2.7	5.4	2.6	5.3	-	-
Substitution rate 1/	-	0.26^{c}	0.54^{b}	0.73^{a}	0.43^{b}	0.08	***
Total	13.4^{d}	15.4^{b}	15.9^{ab}	14.1^{c}	16.4^{a}	0.25	***
Metabolisable energy offered 2/							
As pasture	162	162	162	162	162	-	-
As concentrate	-	31	63	31	63	-	-
Total	162	193	225	193	225	-	-
Metabolisable energy eaten 2/							
As pasture	118^{a}	112^{b}	93^{d}	101^{c}	98^{c}	2.2	***
As concentrate	-	31	63	31	63	-	-
Total	118^{e}	143^{c}	156^{b}	132^{d}	161^{a}	2.2	***
Crude protein eaten 2/							
As pasture	1591^{a}	1515^{ab}	1252^{c}	1370^{abc}	1322^{bc}	120	**
As concentrate	-	456	913	744	1516	-	-
Total	1591^{d}	1914^{c}	2165^{b}	2114^{b}	2838^{a}	52	***
Crude protein concentration in total diets (%)	11.9	12.4	13.6	15.0	17.3	-	-

1/ calculated as pasture DM intake by cows in the PF group minus pasture DM intake by cows in the supplemented groups then divided by concentrate DM intake by the cows on the particular supplemented group).

2/ calculated from those results shown in Tables 4.2.2 and 4.2.3.

4.2.5.3 Animal Performance

The mean values for yields of milk, milk fat, fat concentration and liveweight change for treatment groups are presented in Table 4.2.6. The mean values of milk yield before the start of the experiment were similar in all treatment groups ($p>0.05$). During the experimental period the unsupplemented cows had lower values of milk yields and milk fat yield than the supplemented cows ($p<0.001$). No significant differences in milk yield between the supplemented cows (17PL, 17PH, 30PL and 30PH) were observed. Yields of fat in the 17PH and 30PH cows were similar to the 30PL cows but were higher than the 17PL cows. Concentrate supplementation reduced fat concentration in all supplemented groups relative to the pasture fed group although this difference was not statistically significant ($p>0.05$).

Figures 4.1 to 4.3 show the changes in milk yield, milk fat yield and fat concentration over the experimental period for the five treatment groups.

The unsupplemented cows had a significantly lower value for final liveweight than the supplemented cows ($p<0.001$). All supplemented cows gained weight. The cows receiving the low degradable protein supplement tended to gain more weight than the others.

The unsupplemented cows had a significantly lower value for calculated net energy retention than the supplemented cows ($p<0.001$).

Table 4.2.6 **Mean performance values for initial, and experimental periods (adjusted by covariance to remove effects of differences present in initial period) for yields of milk (kg/cow daily), milk fat (g/cow daily), fat concentration (%), final liveweight (kg), liveweight change (g/day) and calculated net energy retention (MJ/day).**

Details:	T1 PF	T2 17PL	T3 17PH	T4 30PL	T5 30PH	SEM	Sig.
Initial							
Milk yield	12.4	12.6	12.4	11.6	11.5	1.1	NS
Fat yield	536	551	555	538	516	59	NS
SNF yield[1/]	1.05	1.07	1.05	0.98	0.98	-	-
Fat conc.	4.35	4.38	4.48	4.71	4.49	0.40	NS
SNF conc.[1/]	8.45	8.48	8.47	8.42	8.51	-	-
Experiment							
Milk yield	4.8^{b}	9.2^{a}	11.3^{a}	10.1^{a}	11.7^{a}	0.5	***
Fat yield	221^{c}	390^{b}	479^{a}	439^{ab}	495^{a}	30	***
Fat conc.	4.64	4.25	4.26	4.47	4.36	0.16	NS
SNF yield[1/]	0.40	0.78	0.97	0.87	1.04	-	-
SNF conc.[1/]	8.36	8.46	8.61	8.63	8.90	-	-
Responses							
Milk yield (kg/kg conc.)	-	1.6	1.2	2.0	1.3	-	-
Fat yield (g/kg conc.)	-	63	49	84	52	-	-
Final LW	361^{c}	384^{b}	387^{ab}	395^{ab}	401^{a}	3.1	***
LW change	-411^{c}	146^{b}	202^{ab}	414^{a}	548^{a}	128	***
Net energy retention (Net energy in milk plus liveweight)[2/]	9^{c}	39^{b}	49^{a}	46^{ab}	53^{a}	5.3	***

The results shown are covariance adjusted means.

1/ pooled samples from each treatment (no statistical test possible).

2/ net energy in milk estimated from equation 4 of Tyrrell and Reid (1965) net energy in liveweight assumed to be 21.5 MJ/kg gain (ARC, 1980).

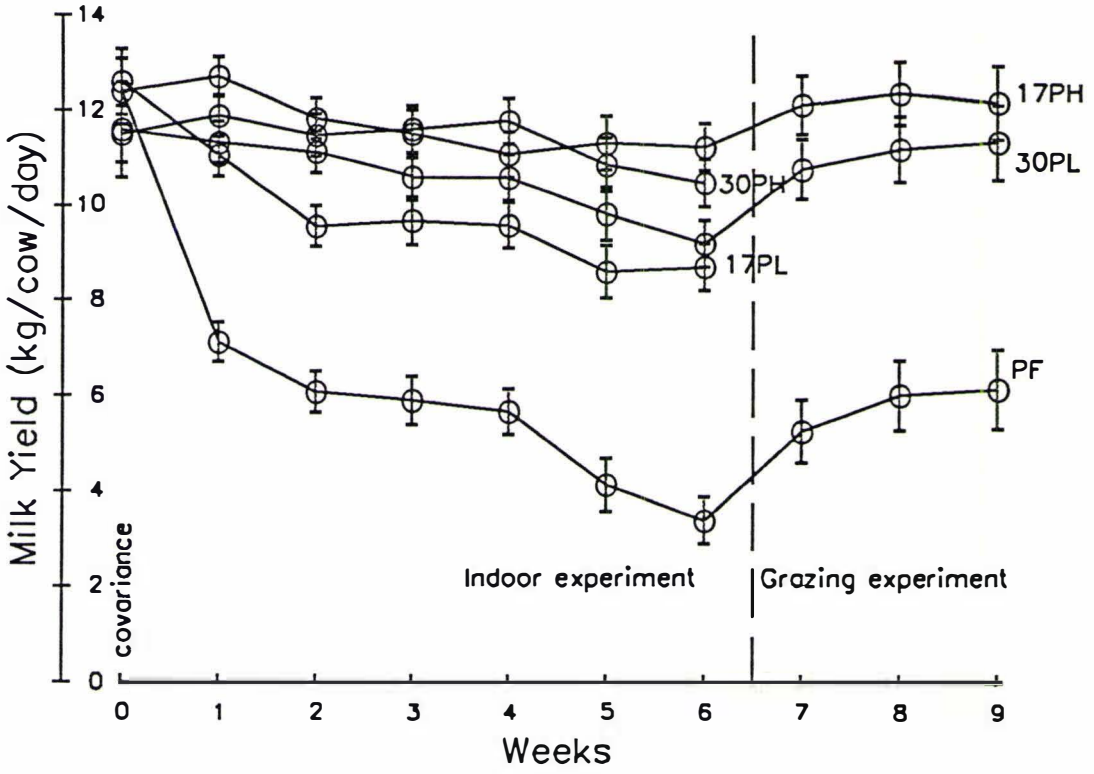

Figure 4.1 The effect of type and amount of concentrate supplementation on milk yield. Vertical bars indicate standard error of least square means.

PF = pature only.

17PL = pasture plus 3 kg of 17% CP (locally used; high degradable protein) concentrate.

17PH = pasture plus 6 kg of 17% CP (locally used; high degradable protein) concentrate.

30PL = pasture plus 3 kg of 30% CP (low degradable protein) concentrate.

30PH = pasture plus 6 kg of 30% CP (low degradable protein) concentrate.

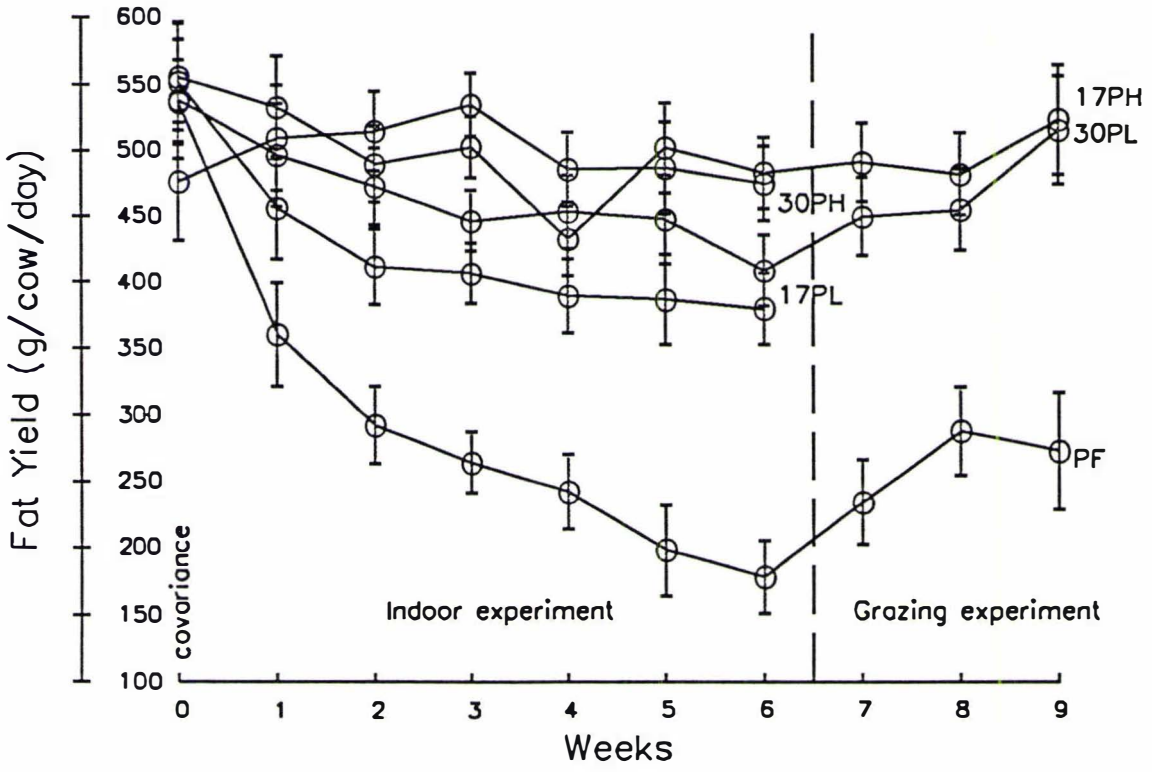

Figure 4.2 The effect of type and a ount of concentrate supplementation on milk fat yield. Vertical bars indicate standard error of least square means. Abbreviations as in Figure 4.1.

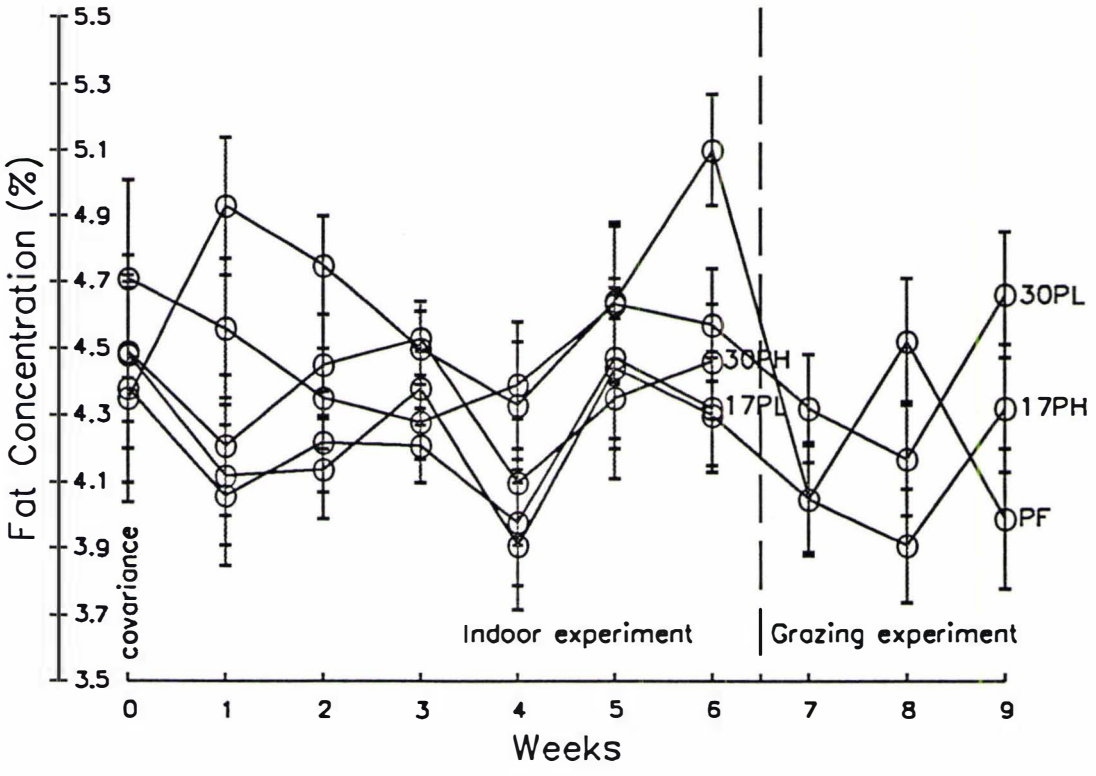

Figure 4.3 The effect of type and amount of concentrate supplementation on milk fat concentration. Vertical bars indicate standard error of least square means. Abbreviations as in Figure 4.1.

4.2.5.4 Overall Relationships Between Nutrition And Performance

A curvilinear relationship between ME intake and milk yield for individual cows (and treatment means) was found and is shown in Figure 4.4.

The relations between ME intake, and net energy retention (milk plus liveweight gain), net energy in milk and in liveweight are shown in Figure 4.5. While ME intake was an important determinant of production the high protein concentrate also resulted in slightly higher retentions of energy although the differences were not statistically significant.

Assuming that the protein degradability of low quality tropical pasture was 0.50 (Corbett *et al.*, 1987; AAC, 1990) and the concentrates had the degradabilities shown in Table 4.2.3. (0.65 and 0.53 for 17%CP locally used and 30%CP low degradable protein concentrates respectively), the estimated supplies of RDP and UDP to the cows were calculated (Table 4.2.7). The resulting RDP/ME ratios in the rations consumed are also presented in this Table. The intakes of UDP and the ratios RDP/ME increased progressively from treatment 1 through to 5 and the high plane of concentrate feeding also increased the RDP intakes for both types of concentrate. The associations between RDP/ME, and net energy retention (milk plus liveweight), net energy in milk and in liveweight are shown in Figure 4.6.

By combining the data for milk yield and liveweight change (as MJ net energy), it was possible to examine the influence of concentrate supplementation on the apparent utilisation of metabolisable energy intake (Table 4.2.8). Supplementation of pasture with concentrates clearly increased ME intakes and the extent of the effect depended on level of feeding (See also Table 4.2.5). The partitioning of energy between milk production and liveweight gain was different for the two concentrates in that the 30% protein ration resulted in more net energy in liveweight gain than the 17% protein ration. The 'apparent' efficiencies of retention of energy (milk plus liveweight gain), relative to ME available above maintenance, was much higher for the concentrate supplemented groups and tended to be higher for the 30% protein compared to the 17% protein ration. The relationship between net energy in milk, in liveweight, and net energy retention (milk plus liveweight), and ME available above maintenance is shown in Figure 4.9.

Table 4.2.7 The supply of rumen degradable protein (g/day, RDP), undegradable protein (g/day, UDP) and the ratio of RDP/metabolisable energy intake (g/MJ).

Details:	T1 PF	T2 17PL	T3 17PH	T4 30PL	T5 30PH
RDP supply[1/]					
As pasture	796	758	626	685	661
As concentrates	-	296	593	394	803
Total	796	1054	1219	1079	1464
UDP supply[1/]					
As pasture	796	758	626	685	661
As concentrates	-	160	320	350	713
Total	796	918	946	1035	1374
Total ME intake	118	143	156	132	161
RDP/ME intake	6.8	7.4	7.8	8.2	9.1

1/ Assuming protein degradability of pasture is 0.50 (Corbett *et al.*, 1987). Protein degradabilities of concentrates were estimated from those values reported in Chapter 6.

Table 4.2.8 Estimates of the partitioning of metabolisable energy intake (MJ), by treatment groups.

Details:	T1 PF	T2 17PL	T3 17PH	T4 30PL	T5 30PH	SEM	Sig.
(1) Total ME intake	118^{e}	143^{c}	156^{b}	132^{d}	161^{a}	2.2	***
(2) ME requirement[1/] for maintenance	49	53	54	53	52	2.6	NS
(3) Net energy in milk[2/]	18^{d}	36^{c}	45^{a}	37^{bc}	42^{ab}	2.6	***
(4) Net energy in LWG[3/]	-9^{d}	3^{c}	4^{bc}	9^{ab}	12^{a}	2.8	***
(5) Total Energy Retention[4/]	9^{c}	39^{b}	49^{a}	46^{ab}	53^{a}	3.7	***
(6) MEI - ME_m[5/]	69^{d}	90^{b}	102^{a}	79^{c}	108^{a}	3.2	***
(7) Efficiency[6/]	0.14^{c}	0.44^{b}	0.49^{ab}	0.59^{a}	0.50^{ab}	0.05	***

1/ $ME_m = 0.60LW^{0.75}$
2/ From Equation 4 of Tyrrell and Reid (1965).
3/ 21.5 MJ/kg gain (ARC, 1980).
4/ (3) + (4).
5/ (1) - (2).
6/ (5)/(6).

Because the productivity of cows in the different treatments was related to both energy and protein contents of the concentrates, an attempt was made to separate out their individual effects by using multiple regression analyses (Table 4.2.9). Milk yield, net energy in milk, net energy in liveweight and total energy retention (milk plus liveweight) were all related to intake of ME. Total energy retention was also related to intakes of ME and CP.

Table 4.2.9 **Significant regression equations describing the association between the intakes of metabolisable energy (MEI, MJ/cow daily) and crude protein intakes (CPI, g/cow daily), and milk yield (kg/cow daily), net energy in milk (MJ/cow daily), net energy in liveweight (MJ/cow daily) and total energy retention (MJ/cow daily).**

Regression equations			r^2
Milk Yield	=	-9.6 + 0.1MEI (2.6) (0.02) ***	0.58
Total energy retention	=	-74.8 + 0.8MEI (16.2) (0.1) ***	0.56
	=	-63.7 + 0.5MEI + 0.01CPI (16.3) (0.15) (0.004) *** ***	0.61
Net energy in milk	=	-34.6 + 0.5MEI (9.8) (0.07) ***	0.57
Net energy in LWG	=	-40.3 + 0.3MEI (10.2) (0.07) ***	0.31

Correlation between the intakes of ME, RDP, UDP or total CP and animal performance were also examined. The results are given in Table 4.2.10. The intakes of RDP, UDP or total CP were significantly ($p<0.001$) correlated to energy retention (ER), net energy in milk (ME), net energy in liveweight (LWE) or milk yield (MY). Milk yield was positively related to MEI ($r = 0.76$), RDP ($r = 0.73$), and CPI ($r = 0.64$). A slight but significant relation ($r = 0.50$; $p<0.01$) was observed between UDP intake and milk yield.

4.2.5.5 Summary of the Results

1. Concentrate supplementation reduced forage DM intake, ranging from 0.26 to 0.73 kg/kg concentrate DM consumed, in all treatments.

2. Yields of milk and milk fat were increased by concentrate supplementation. Milk yields between the supplemented groups were not significantly different although the level of concentrate supplementation tended to increased milk yield at a greater high extent than the low level of supplementation.

3. The supplemented cows gained weight whereas the unsupplemented cows lost weight.

4. The 'apparent' efficiency of use of ME above maintenance was lowest in the unsupplemented group, however, those values for the supplemented groups were still low relative to those reported in cows on the temperate pastures.

Table 4.2.10 Correlation coefficients between performance and nutrition (the lower figures are probability > |R| under Ho: Rho=0 / n=40).

	MY	ER	ME	LWE	MEI	RDP	UDP	CPI
MY	1.000 0.000							
ER	0.906 0.0001	1.000 0.000						
ME	0.996 0.0001	0.915 0.0001	1.000 0.000					
LWE	- -	0.874 0.0001	- -	1.000 0.000				
MEI	0.765 0.0001	0.755 0.0001	0.761 0.0001	0.575 0.0001	1.000 0.000			
RDP	0.732 0.0001	0.802 0.0001	0.740 0.0001	0.694 0.0001	0.930* 0.0001	1.000 0.000		
UDP	0.496 0.0011	0.648 0.0001	0.515 0.0007	0.659 0.0001	0.714* 0.0001	0.905 0.0001	1.000 0.000	
CPI	0.635 0.0001	0.747 0.0001	0.649 0.0001	0.694 0.0001	0.848* 0.0001	0.979 0.0001	0.973 0.0001	1.000 0.000

* These parameters are not independent to each other.

*** * The probability that a R statistic would obtain a greater absolute value than that observed given that the true parameter is 0.**

4.2.6 DISCUSSION

4.2.6.1 Effect of Concentrate Supplementation on Herbage Intake

In the present study, DM intake of 13.4 kg/cow daily by the unsupplemented cow was relatively high for 61 % DMD pasture compared with those data obtained on temperate pastures (Hodgson, 1977). Minson (1980) examined the relationship between the voluntary intake of a wide range of temperate and tropical grasses, and the digestibility of the dry matter, and at a given digestibility (for example 60%) the mean voluntary intake of tropical grasses was 20% higher than for temperates. This higher intake of the tropical grasses is apparently due to a difference in structures, as tropical grasses, with a digestibility of 60%, are young and relatively leafy while temperate grasses of similar digestibility are very mature and stemmy.

Among the possible factors which may affect the dry matter intake of forage by ruminants, the amount of concentrates fed as a supplement is one of the most important. Generally, with dairy cows receiving forage *ad libitum*, the intake of roughage is reduced when concentrates are fed (Meijs, 1981). The reduction in forage dry matter intake per unit of additional concentrates is called the substitution rate.

Forage intakes of the supplemented cows in the present study were all decreased by consumption of concentrates. However, the extent of reduction was variable. The substitution rates ranged from 0.26-0.73 kgDM reduction in forage intake per kgDM of additional concentrate eaten. Grazing trials with lactating cows in early lactation have shown that concentrate feeding reduced herbage consumption (Jennings and Holmes, 1984; Meijs and Hoekstra, 1984; Arriga-Jordan and Holmes, 1986; Meijs, 1986; Stakelum, 1986 a,b,c; Suksombat, 1988). The substitution rate varied between 0.03 and 0.79 kgDM/kg concentrate DM eaten. In reviewing 11 indoor experiments covering the range 0 to 5.2 kg concentrate DM, Meijs (1981) showed a mean substitution rate of 0.45, which is similar to the average substitution rate of 0.49 recorded in the present study. These results confirmed the early work of Leaver *et al.* (1969) who reported a substitution rate of 0.55 kg of herbage OM/kg concentrate OM consumed.

Generally, increases in substitution rates with increasing levels of concentrate intake have been obtained in zero grazing experiments (Meijs, 1981), although some authors have not found this relationship in indoor trials (Taparia and Davey, 1970; Tayler and Wilkinson, 1972) or in grazing trials (Meijs and Hoekstra, 1984). In the present study, an increase in substitution rate with increasing levels of concentrate intake was found only when the locally used concentrates were fed but was not found when the high protein concentrates of low degradability were fed. In the latter case, the extra 2.7 kgDM received by the 30PH cows did not cause a significant decrease in pasture intake, compared with the 30PL cows.

Clements *et al.* (1989), compared cows receiving temperate grass silage and either 3, 5 or 8 kg/cow daily of concentrate containing 18% CP; or cows received grass silage and either 2,4 or 6 kg/cow daily of concentrate containing 30% CP. In both cases, significant responses in milk yield of respectively 1.34 and 1.07 kg/kg additional concentrate consumed for the 18% CP and the 30% CP diets were obtained by increasing the feeding level of the concentrates. However, a much lower substitution rate, 0.075 kg silage DM/kg additional concentrate consumed, was obtained with the 30% CP concentrates compared to that obtained when 18% CP concentrates were used (0.22 kg silage DM/kg additional consumed). In the present study, at the high level of concentrate feeding the substitution rates were similar for the 17% CP and 30% CP concentrate groups.

In surveying the literature, Oldham (1984) concluded that changes in protein input result in a change of digestibility of the ration. Increases in dry matter digestibility in lactating cows offered rations of differing protein concentration (%CP/DM) were generally achieved when crude protein concentration was increased up to approximately 15% CP in the ration. Further increases in CP concentration in the ration usually had no additional effect on DM digestibility, although a few experiments showed increases in digestibility when CP concentration was increased up to 20% (Oldham, 1984). Tyrrell *et al.* (1981) offered the same feeds, which differed in crude protein concentration, to dry cows at maintenance feeding and to lactating cows at 3.5 times maintenance. Increasing the crude protein content of the ration from 10.8 to around 15% in dry matter had no effect on digestibility with dry cows but had a large effect with lactating cows (digestibility increased by 0.04 to 0.08 digestibility units).

There have been a few recent reports showing increased forage intake and digestibility by steers given a grain-based supplement with a high concentration (27%) of crude protein compared to those receiving a supplement with 13% CP, or even those receiving no supplement (DelCurto *et al.*, 1990; Hannah *et al.*, 1991). Hannah *et al.* (1991), for example, supplemented 1.8 kgDM concentrates (containing either 12.8% CP or 27.1% CP) to steers fed dormant bluestem-range hay and reported that steers receiving 27.1% CP concentrate consumed 5.17 kgDM hay compared to 3.13 kgDM in those receiving 12.8% CP concentrate. An increased dry matter digestibility of the total ration in those trials reflected the inclusion of concentrate and probably the extremely low quality forage (2.3% CP, 79.1% NDF) eaten as a basal diet. In addition, increases in the concentration of protein in the concentrates in those trials would have increased the supply of RDP in the ration and hence increased fibre digestion particularly in the very low RDP supply from basal diet.

In the present study, at the low level of concentrate feeding, an increase in crude protein concentration in the concentrate did not result in an increase in forage intake (12.7 and 11.5 kgDM/cow daily for 17% and 30% CP respectively, compared with 13.4 kgDM/cow daily no supplement). In contrast, at the high level of concentrate feeding forage intake was increased slightly with increasing crude protein concentration in the concentrate (10.5 and 11.1 for 17% and 30% CP respectively). The differences in forage intake response to crude protein concentration was probably due to the fact that at the low level of feeding, both groups of cows (17PL and 30PL) received similar amounts of RDP supply despite the high concentration of crude protein in the 30PL group, due to low degradability of protein in the 30PL treatment (1054 and 1079 g/cow daily respectively) while at the high level of feeding cows with 30% CP had a higher supply of RDP than cows with 17% CP (1464 and 1219 g/cow daily; See Table 4.2.7).

In the present study, at the low level of concentrate supplementation (17PL and 30PL), the high protein (low degradable) supplement resulted in a lower intake of pasture. In contrast, at a high level of concentrate supplementation (17PH and 30PH), the high protein (low degradable) tended to increase the intake of pasture (due to a smaller decrease, relative to the unsupplemented group). This could have been due to effects of an improved amino acid supply, or amino acid balance in the animal, on the intake control mechanisms as found for sheep (Egan and Moir, 1965). The intake of UDP at

the low level of concentrate feeding (17PL and 30PL) was similar for the 17% and 30% CP groups, while at the high level of concentrate feeding, the intake of UDP by the 30% CP cows (30PH) was higher than the 17% CP cows (17PH).

An insufficiency or imbalance of absorbed amino acids can limit metabolic pathways within the animal, reducing the rates of utilisation of substrates and thus imposing a limit to voluntary intake (Forbes, 1986). Egan and Moir (1965) found that infusion of casein into the duodenum of sheep offered a low-protein straw caused a rapid increase in intake while rate of digestion in the rumen was reduced. This was in contrast to similar infusion into the rumen which resulted in a slower increase in intake with a significant increase in ruminal digestion. It seems likely that deficiencies of essential amino acids result in reduced activities of key enzymes in metabolic pathways which are responsible for the removal of nutrients from circulation. These accumulate and may cause prolonged stimulation of chemoreceptors which form part of the negative feedback pathway to the centres of the brain controlling intake (Forbes, 1986).

4.2.6.2 Effect of Concentrate Supplementation on Animal Performance

The objective of the present study was to determine the effect of supplement fed at two levels, and containing protein of high or low degradability on animal performance.

In the present study, it was clear that dairy cows fed solely on low quality tropical pasture produced lower yields of milk and milk fat, and also lost weight, compared with those given supplements. This suggests that, despite considerable supply of nutrients (e.g. 118 MJME/cow daily), the unsupplemented cows may have received an imbalance of nutrients which restricted their ability to produce high milk yield and gain in liveweight. The low supply of RDP relative to metabilisable energy intake (6.8 g RDP/MJME; Table 4.2.7) would probably have led to a reduced microbial protein yield from the rumen (ARC, 1980). Consequently, the milk yield of unsupplemented cows was much lower than would have been predicted from ME intake because of limitations imposed by RDP supply. The intake of 118 MJME daily by the PF cows, in theory, should have been able to produce approximately 0.5 kg milk fat, or 12 kg milk (118 MJME intake - 50 MJME maintenance requirement = 68 MJME).

Alternatively, the low supply of RDP in the unsupplemented cows may have led to reduced fermentation of organic matter in the rumen. This may have caused an overestimate of ME intake in the unsupplemented cows. The extremely low calculated 'apparent efficiency of ME utilisation above maintenance' of 0.14 probably reflected the overestimate of ME intake by the unsupplemented cows. It should be realised that an error in estimated ME intake would result in a difference in calculated apparent efficiency of ME utilisation. For example, if the digestible organic matter decreased by 3% units, the ME available above maintenance would have been reduced by 4 MJ.

From Table 4.2.8, only the 'apparent' efficiency of utilisation of ME above maintenance for cows on the 30PL ration was close to 0.6 as suggested by ARC (1980, 1984), while for other rations it was considerably lower. The calculated partition of ME (Table 4.2.8) are approximations rather than exact measures of M/D value of feeds, of maintenance requirements and are probably subject to errors arising from the difficulty of weighing animals precisely and possible changes in the content of digestive tract. One of these or their combination probably contributed to the underestimated 'apparent' efficiency of ME utilisation.

Supplementation of roughages with feeds containing readily fermentable carbohydrate can result in a reduction in the digestibility of the roughage (Milne *et al.*, 1981). Mould *et al.* (1983) found that a major cause is rapid fermentation of the supplementary carbohydrate resulting in a reduction in rumen pH which consequently inhibits bacterial cellulolytic activity. They also found that when a hay was fed with rolled barley, the hay DM digestibility could be reduced by as much as 0.2 units (from 0.51 to 0.31) and the digestibility of the whole diet reduced by about 0.09. The prediction of M/D value of feeds in the present study used the values from *in vitro* determination and did not take into account a possible reduction in the diet digestibility due to feeding concentrate. Consequently, the M/D values of the feeds in the present study were possibly overestimated.

There appears to be no broadly based equation for animals fed tropical feeds to predict maintenance requirement. The present study adopted the value of $0.60LW^{0.75}$ (ARC, 1980) to estimate the maintenance requirement of ME. This value is based on research obtained from animals being fed with a diet M/D higher than 10. AAC (1990) suggested that with diet M/D greater or less than 10, the ME is used for maintenance

with respectively greater or lesser efficiency, and ME_m (MJ/day) is correspondingly less or more. The estimated M/D value of pasture in the present study was less than 10 and thus the ME_m may have been more than $0.60LW^{0.75}$. The estimate of ME requirement for maintenance was possibly low in the present study. For example, if a value of $0.70LW^{0.75}$ had been used, the calculated ME requirement for maintenance would have increased by 9 MJ and hence increased the calculated 'apparent' efficiency of ME utilisation above maintenance by 0.05 to 0.10 unit.

The low calculated 'apparent' efficiency of utilisation of ME above maintenance in the PF and 17PL cows would have been due to the fact that these cows had previously been on a high plane of feeding (6 kg concentrate plus pasture). The unsupplemented cows and the 17PL cows had been fed at a reduced level of feeding during the experimental period (0 and 2.7 kgDM/cow daily respectively). Changes in level of feeding are reflected in milk output and in changes in body weight (Broster, 1971, 1972; Grainger *et al.*, 1982; Broster and Broster, 1984; Broster *et al.*, 1984; Stockdale *et al.*, 1987). Bryant and Trigg (1982) summarised several trials from Australia and New Zealand and concluded that an increase in DM intake of 1.0 kg caused an increase of 39 g milk fat. They found that the extent of this increase is proportional to the duration and severity of change in level of feeding (Bryant and Trigg, 1979; Grainger and Wilhelms, 1979). In addition, the response in milk yield to change in the level of feeding is greater at a low level of feeding than at a high level, is greater in higher than in lower yielding cows, and is greater in early lactation than in mid-late lactation (Broster *et al.*, 1981; Broster and Broster, 1984).

Concentrate supplementation increased yields of milk and milk fat in the present study. The responses ranged from 1.2 to 2.0 kg milk/kgDM concentrate consumed (calculated from 0 to 2.7 and to 5.4 kgDM concentrate). Although the differences between the supplemented groups were not statistically significant, supplementation at the low level with low degradable protein concentrate (30PL) gave a better response than the others (2.0 kg milk/kgDM concentrate).

The much higher responses in milk production to concentrate supplementation in the present study than in other studies (Leaver *et al.*, 1968; Jennings and Holmes, 1985) was probably due to the fact that in this experiment the unsupplemented cows received low quality pastures containing 12% CP, 61% DMD and estimated ME of 8.8

MJ/kgDM, and a very low total effective intake. Also the unsupplemented cows had been put onto a reduced level of feeding during the experimental period. The unsupplemented cows, therefore, dropped dramatically in milk yield (from 12 kg/cow daily to 5 kg/cow daily) while the supplemented cows maintained their milk yield.

However, when comparison was made between the two levels of concentrate feeding (2.7 and 5.4 kg extra concentrate DM consumed) the response lay between 0.6 and 0.8 kg milk/kg concentrate DM consumed. Another experiment conducted at the same site as the present study (Lekchom *et al.*, 1989) also found that the response ranged from 0.7 to 0.4 kg milk/kgDM concentrate consumed when grazing dairy cows were supplemented with a local concentrate at different levels up to 15 kgDM/cow daily.

Care must be taken when expressing the response of milk yield to /kgDM concentrate consumed. For example, in the present study it was found that the average response was 1.8 kg milk/kgDM concentrate eaten when calculated from 0 to 2.7 kgDM supplement, but the average response reduced to 0.7 kg milk/kgDM concentrate eaten when calculated from 2.7 to 5.4 kgDM supplement. The results published often compare the response to extra concentrate DM eaten (Journet and Demarquilly, 1979; Jennings and Holmes, 1985), rather than the response to some supplement compared with no supplement.

When the data for milk yield were analysed as a 2 x 2 factorial design (2 level of concentrate feeding and 2 concentrations of protein in the concentrates; Low and High, 17% and 30% CP), the effect of protein (17% CP, high degradability or 30% CP, ;low degradability) was not significant, but the effect of level of concentrate feeding (2.6 and 5.4 kgDM/cow daily) was significant ($p<0.01$). No interactive relationship between the two factors was found.

Supporting evidence to this can be seen from the ME and crude protein consumption data. The 17PH and 30PL cows had similar crude protein intakes (2165 and 2114 g/cow daily respectively) but different ME intakes (156 and 132 MJ/cow daily). This tended to result in slightly higher milk yield in the 17PH cows than the 30PL cows. In contrast, the 17PH and 30PH cows had similar ME intakes (156 and 161 MJ/cow daily) but different crude protein intakes (2165 and 2838 g/cow daily). Despite higher crude protein intake of the 30PH cows, they produced similar milk yield to the 17PH

cows. Thus it could be concluded that the level of ME intake played the major role in production response rather than the crude protein in the ration. The multiple regression showed that the animal performance (milk yield and energy retention) was significantly ($p<0.001$) related to MEI.

Additional protein supplied to the intestines of cows, either as abomasal infusions or given as dietary supplements of relatively undegradable protein has been shown to increase milk yield (Orskov *et al.*, 1977; 1981; Stobbs *et al.*, 1977; MacRae, 1983). The effect has generally been attributed to the provision of extra essential amino acids for milk protein synthesis (Clark, 1975; Orskov *et al.*, 1977). In the present study, at a comparable level of concentrate feeding, increased UDP supply by the supplementation of low degradable protein tended to result in a slightly higher milk yield (average 0.6 kg milk/cow daily) and liveweight gain than the locally high degradable protein concentrates.

To explain increases in milk yield with increasing amino acid supply (by increases in UDP), it could be postulated either that increased amino acid input has made more nutrients available to increase milk production, or that amino acids may have a direct effect on milk synthesis (Oldham, 1984).

4.2.6.3 Overall relationships between nutrition and performance

In Table 4.2.7, it was assumed that 0.50 of the crude protein intake from the pasture was degraded and this is probably a more accurate value than the 0.80, often found in temperate pastures (Corbett *et al.*, 1987). In 17 studies with sheep grazing temperate grasses and legumes with OM digestibility of 0.65 or higher, Corbett and Pickering (1983) found that on average 0.86 of crude protein intake was degraded. These results have been confirmed by Beever and Siddons (1986). For three pastures with OM digestibility of 0.62, the mean protein degradation was 0.74 but there is little information for more fibrous forage of low digestibility and CP content such as in the present study. McMeniman *et al.* (1986), for example, observed the protein degradability of tropical pastures (9.5% CP and 0.50 OMD) of 0.37-0.58 (mean 0.48). Tropical grass species have a C_4 photosynthetic pathway which results in higher fibre

contents than in temperate grass species at comparable stage of growth (Norton, 1982). A feature of the C_4 grasses is a thick-walled bundle sheath which is slow to degrade (Akin *et al.*, 1974), which is probably true for the associated crude protein. Much of the crude protein in these forages may be associated with the cell wall, and as little as 0.50 of the total protein may be degraded (Corbett *et al.*, 1987).

Considering the supply of protein in the form of rumen degradable protein (RDP) per unit of metabolisable energy (ME) intake (Table 4.2.7), the PF cows probably had a lower ratio of RDP/ME than that suggested by ARC (1984) i.e. 6.7 compared to 8.1 gRDP/MJME. Consequently, there was insufficient RDP to provide the ammonia concentration to the level at which improved efficiency of microbial protein synthesis (Bines, 1971), increased DM digestibility (Forbes, 1970), increased food intake (Roffler *et al.*, 1983), and finally, increased energy intake (Van Horn *et al.*, 1985) can be obtained. This resulted in a very low milk yield produced by the PF cows.

In the present study, the 30PH cows received higher supplies of RDP and UDP than the others and tended to produce more milk and greater liveweight gain. The RDP/total ME intake ratio increased progressively from Treatment 1 (PF) through to 5 (30PH) with individual values lower and higher than the value needed to maximise microbial N yield in the rumen (ARC, 1984; i.e. 8.1 gRDP/MJME).

When using calculated net energy in milk, in liveweight and total energy retention (milk plus liveweight) plotted against the ratio of RDP/ME (g/MJ, Figure 4.6), there was a quadratic function with the highest net energy retention, net energy in milk and in liveweight gain at a value of about 8.5 gRDP/MJME. This ratio of RDP/ME is in agreement with the value of 8.1 quoted by ARC (1984). In the present study, the 30PL cows had a ratio of RDP/ME of 8.2 g/MJ and showed the highest net energy retention. Thus the results in the present study generally support the estimates given by the ARC (1984).

Also, when relationships between milk yield, calculated net energy in milk, in liveweight and total energy retention (milk plus liveweight) were plotted against the individual intakes of ME, RDP and UDP, there were curvilinear relationships between production parameters and intakes of individual components (Figure 4.5, 4.7 and 4.8).

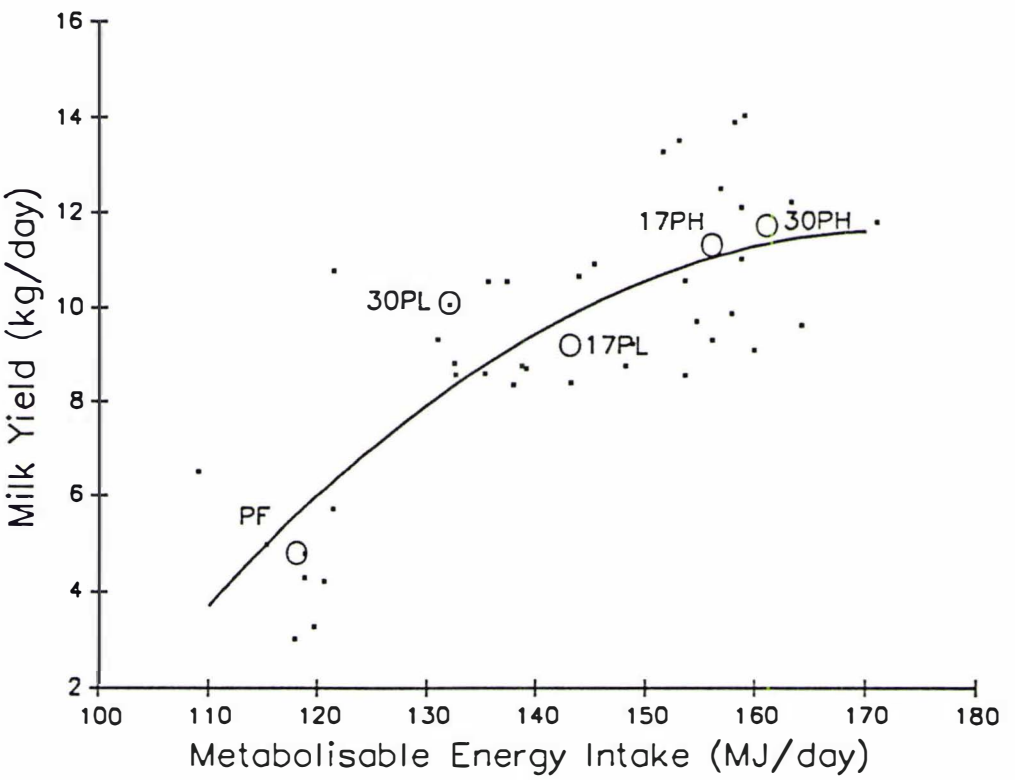

Figure 4.4 Relationship between milk yield and metabolisable energy intake.
Data for individual cows shown (.).
Mean values for each treatment shown (o).

$$\text{Milk yield} = -48.1 + 0.69x - 0.002x^2 \qquad r^2 = 0.60$$

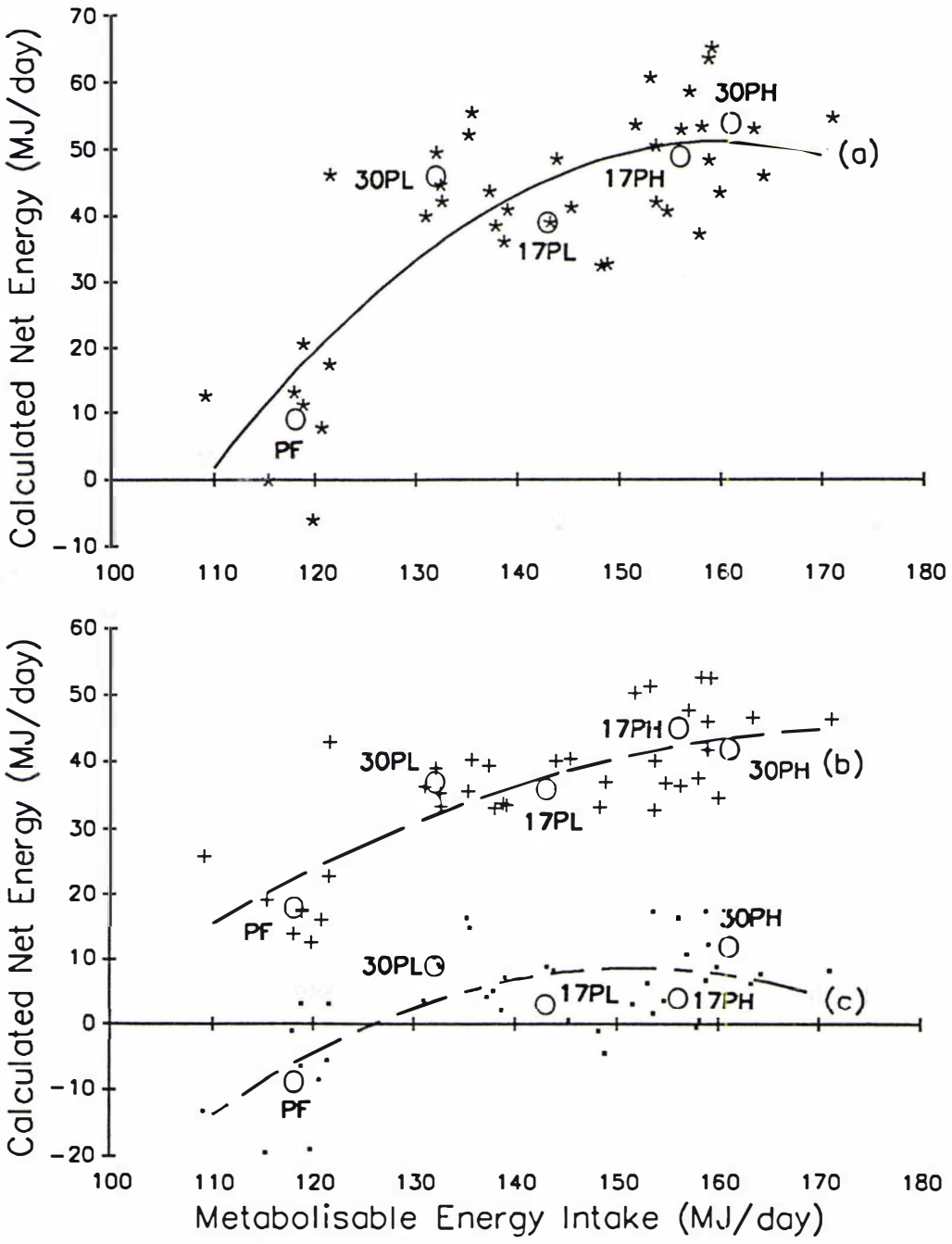

Figure 4.5 Relationship between calculated total net energy retention (a), net energy in milk (b), and net energy in liveweight (c); and metabolisable energy intake.

Data for individual cows shown (., *, +).

Mean values for each treatment shown (o).

(a)	Total	= -451.3 +	6.27x	-	$0.02x^2$	r^2 = 0.63
(b)	Milk	= -167.2 +	2.42x	-	$0.01x^2$	r^2 = 0.58
(c)	Liveweight	= -284.1 +	3.85x	-	$0.01x^2$	r^2 = 0.42

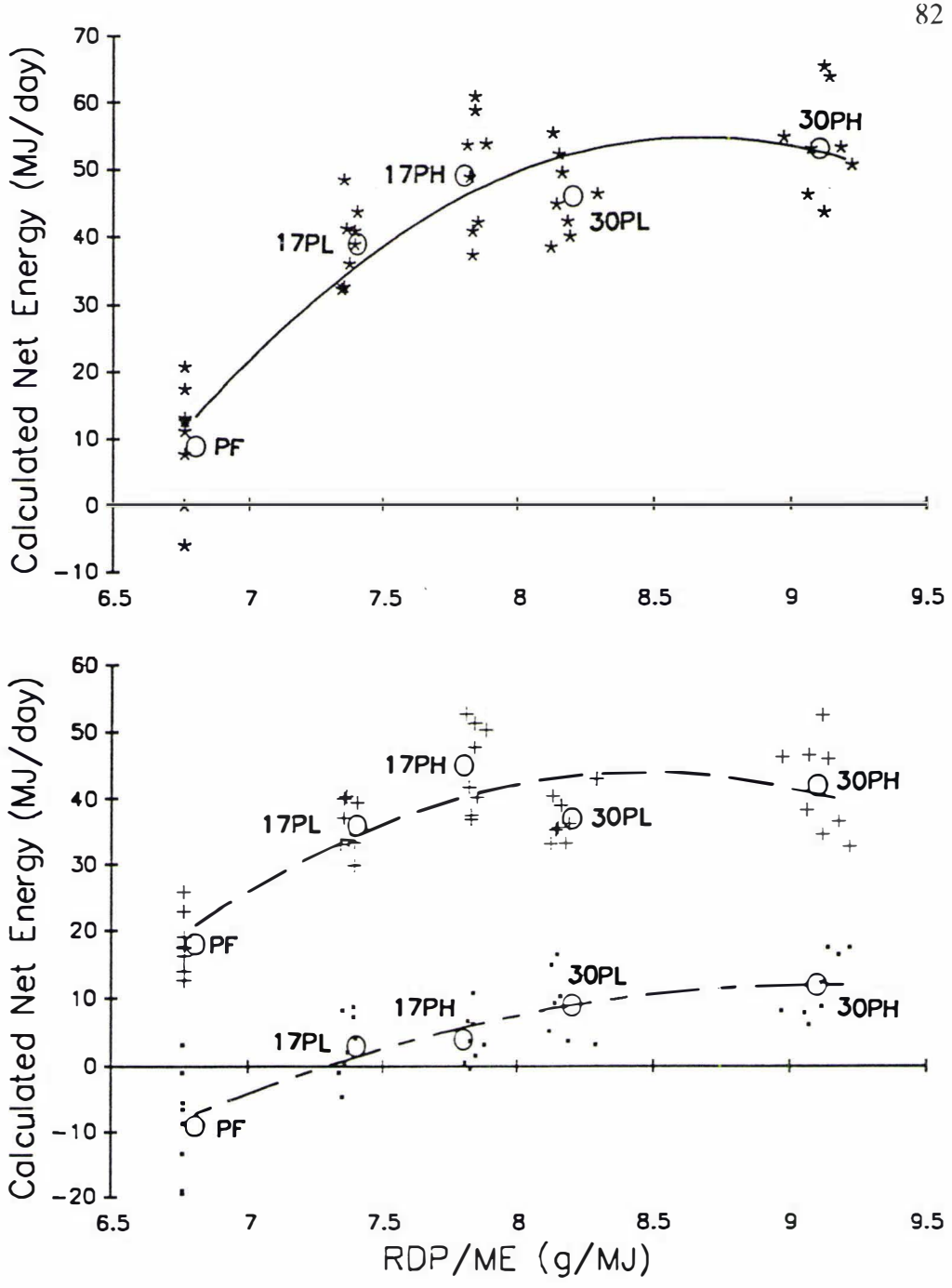

Figure 4.6 Relationship between calculated total net energy retention (a), net energy in milk (b), and net energy in liveweight (c); and the ratio of RDP/ME.

Data for individual cows shown (., *, +).

Mean values for each treatment shown (o).

(a) Total = -844.8 + 207.8x - 12.0x^2 r^2 = 0.78

(b) Milk = -558.9 + 142.4x - 8.4x^2 r^2 = 0.65

(c) Liveweight = -285.9 + 65.3x - 3.6x^2 r^2 = 0.61

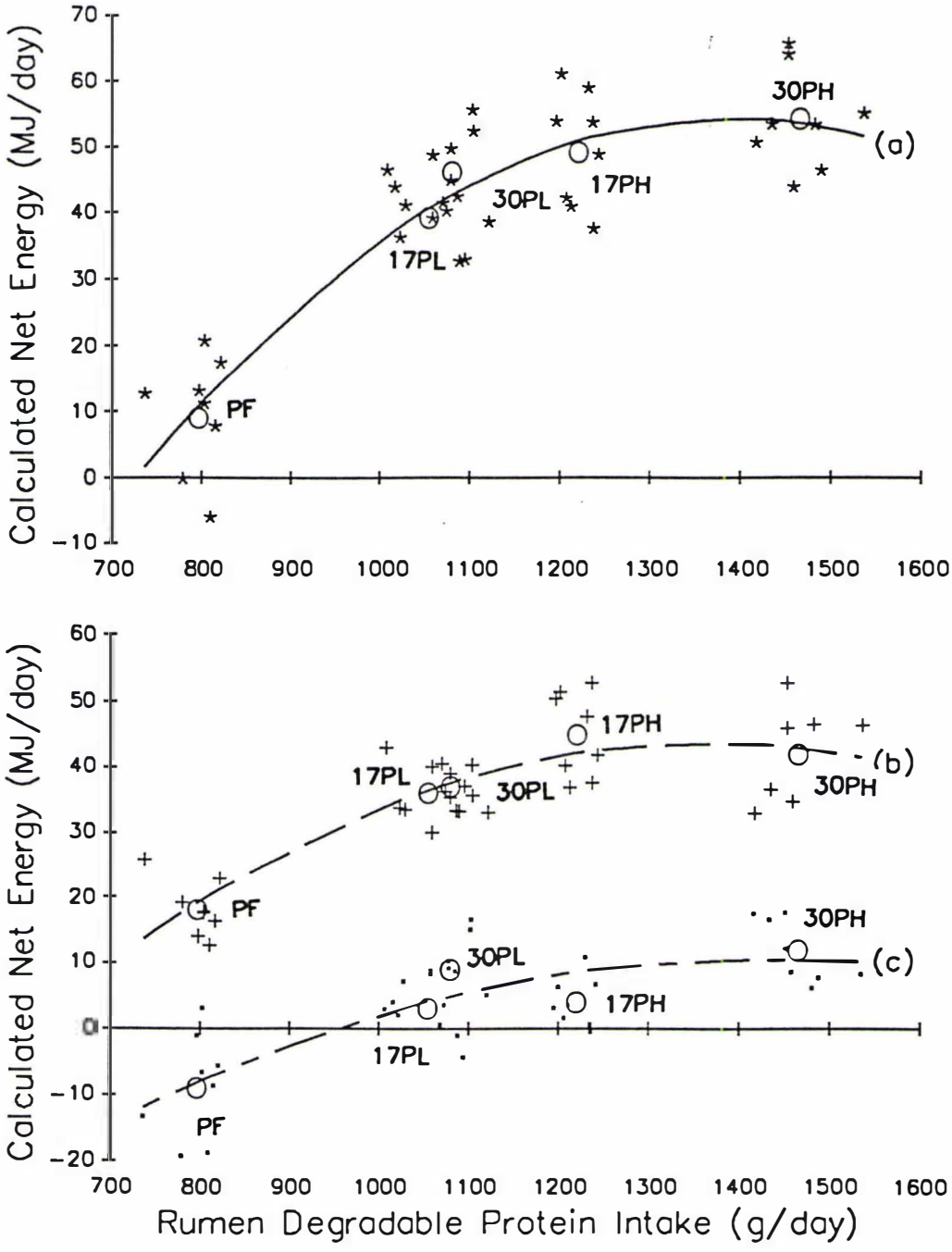

Figure 4.7 Relationship between calculated total net energy retention (a), net energy in milk (b), and net energy in liveweight (c); and rumen degradable protein intake.
Data for individual cows shown (., *, +).
Mean values for each treatment shown (o).

(a)	Total	= -451.3 +	6.27x -	$0.02x^2$	r^2 =	0.63
(b)	Milk	= -167.2 +	2.42x -	$0.01x^2$	r^2 =	0.58
(c)	Liveweight	= -284.1 +	3.85x -	$0.01x^2$	r^2 =	0.42

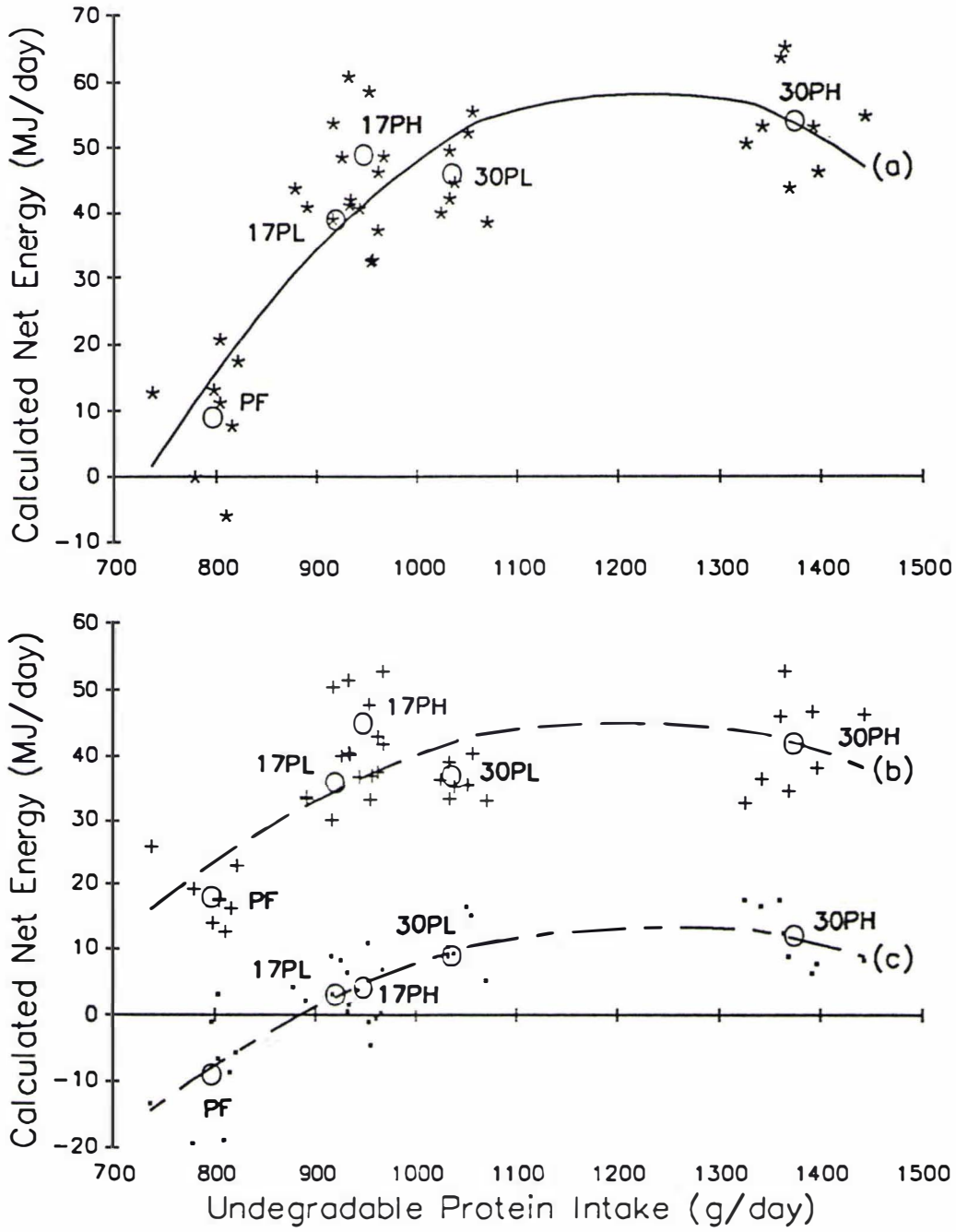

Figure 4.8 Relationship between calculated total net energy retention (a), net energy in milk (b), and net energy in liveweight (c); and undegradable protein intake.

Data for individual cows shown (., *, +).

Mean values for each treatment shown (o).

(a)	Total	= -451.3 +	6.27x -	$0.02x^2$	r^2 =	0.63
(b)	Milk	= -167.2 +	2.42x -	$0.01x^2$	r^2 =	0.58
(c)	Liveweight	= -284.1 +	3.85x -	$0.01x^2$	r^2 =	0.42

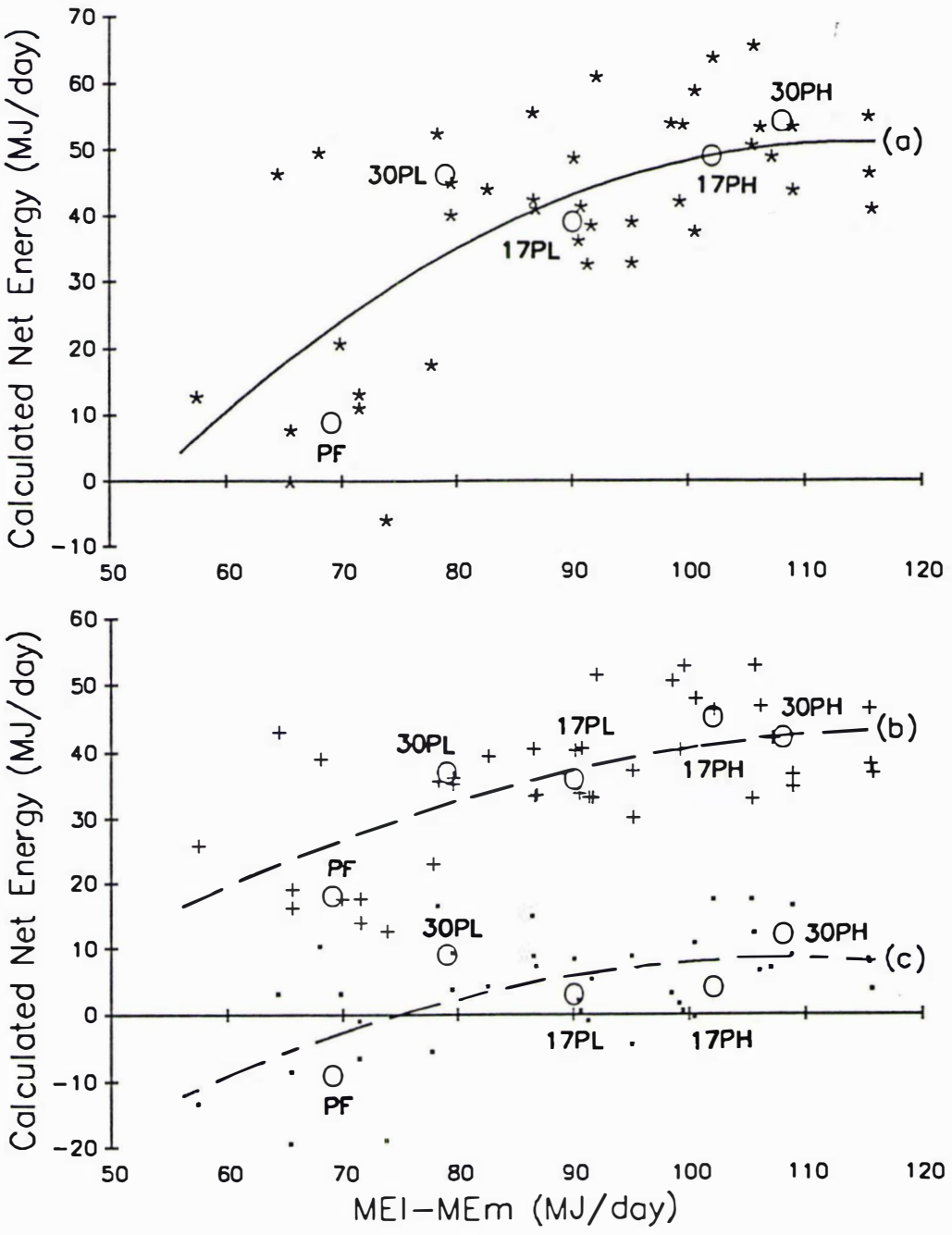

Figure 4.9 Relationship between calculated total net energy retention (a), net energy in milk (b), and net energy in liveweight (c); and metabolisable energy above maintenance (MEI - ME_m).
Data for individual cows shown (., *, +).
Mean values for each treatment shown (o).

(a)	Total	= -129.8 +	3.17x	-	$0.01x^2$	r^2 =	0.42
(b)	Milk	= -50.9 +	1.57x	-	$0.01x^2$	r^2 =	0.37
(c)	Liveweight	= -78.8 +	1.61x	-	$0.01x^2$	r^2 =	0.29

Using the measured values for animal performance, for rumen degradability of protein concentrates (Table 4.2.3), and the assumed value of 0.50 for degradability of protein from tropical pastures (Corbett *et al.*, 1987; AAC, 1990), the intake of both rumen degradable protein (RDP) and undegradable protein (UDP), as given by the Agricultural Research Council (1980), have been calculated (Table 4.2.11). The UDP supplies were adequate to sustain the recorded milk yields in all treatments. However, the supplies of RDP were sufficient only in the 17PH, 30PL and 30PH cows whereas the PF and 17PL cows received insufficient RDP. The deficit in RDP in the PF cows probably caused the dramatic decrease in milk and fat yield, and this is reflected in a lower apparent efficiency of ME utilisation, despite considerable ME apparently available for milk production.

The deficit in RDP supply relative to demand would have reduced microbial protein synthesis and thus a low quantity of microbial protein would have reached the small intestine. Microbial proteins are rich in essential amino acids (Oldham, 1984), if absorbed amino acids are in short supply, the excess of energy-yielding nutrients will then be either stored as fat or oxidised. If excess nutrients were to be stored as fat, then milk production might be less than optimal, but the efficiency of use of ME for milk plus tissue deposition would be little affected (ARC, 1980). If excess nutrients were to be oxidised, then it might be expected that the efficiency of utilisation of ME for milk plus tissue deposition would fall (Oldham, 1984). In the present study, the extremely low calculated 'apparent' efficiency of ME utilisation above maintenance in the PF cows (0.14) was probably due to a deficiency of RDP and of amino acids reaching the intestine relative to energy supply which may be oxidised rather than deposited in the tissue, and to reduced digestibility of the energy.

Table 4.2.11 The estimated supply of rumen degradable protein (g/day, RDP) and undegradable protein (g/day, UDP) to the tissues of the indoor-fed dairy cows (Calculation based on ARC, 1980 and 1984).

Details:	T1 PF	T2 17PL	T3 17PH	T4 30PL	T5 30PH
(1) RDP requirement[1/]	922	1117	1219	1031	1258
(2) RDP supply	796	1054	1219	1079	1464
(3) RDP Deficit/ Surplus	-126	-63	0	48	206
(4) Tissue protein[2/] supplied by microbial protein	389	472	515	436	531
(5) Total tissue protein requirement	162	362	433	429	497
(6) Equivalent UDP requirement |(5)/0.7|	231	517	619	613	710
(7) UDP supply	796	918	946	1035	1374

1/ = 7.8ME (ARC, 1980 and 1984)
2/ = 3.3ME (ARC, 1980 and 1984)

4.2.6.4 An economic assessment of marginal financial returns

An economic assessment was made of the marginal returns from the milk produced per treatment less the cost of the concentrate (Table 4.2.12). It showed that the marginal return was highest when feeding pasture plus a high level of low protein concentrate (17% CP). The marginal returns from 17PL, 30PL and 30PH were similar. Even though the milk response from 30PH cows was slightly larger than from the 17PH cows, the higher cost of 30%CP concentrate caused a lower margin. However, there is an optimum level of feeding above which little or no response will be achieved. Obviously with the present price of milk and cost of concentrate, and the response to concentrate supplementation of more than 1 kg milk/kgDM concentrate found in the present study, Thai farmers will achieve greater profit by relying on improved pasture as their main source of feed for dairy cows and using moderate level i.e. 6 kgDM of concentrate supplementation.

Table 4.2.12 Marginal returns from different levels and types of concentrate supplementation.

Details:	T1 PF	T2 17PL	T3 17PH	T4 30PL	T5 30PH
Milk yield (kg/cow daily)	4.8	9.2	11.3	10.1	11.7
Milk return (NZ$)[1/]	2.64	+2.42	+3.58	+2.91	+3.80
Cost of concentrate[2/] (NZ$)	0.00	+0.59	+1.19	+0.94	+1.91
Marginal surplus (NZ$)	-	1.83	2.39	1.97	1.89

1/ NZ$ 0.55 /kg milk.

2/ NZ$ 0.22 (17%CP); 0.36 (30%CP).
Calculation based on comparison between T2-T5 and T1.

4.2.7 CONCLUSIONS

1. The substitution rate of pasture for the two concentrates differed with feeding level. At the high level of concentrate feeding, the high protein concentrate caused a smaller substitution rate than the low CP diet (0.43 vs 0.54), but the reverse occurred at the low level of feeding (0.73 vs 0.26).

2. It is clear from the present study that the major effect which contributed to differences in animal performance was the ME intake which was influenced by the level of concentrate feeding. However, protein was also important.

3. Amongst the supplemented groups, and within each of the concentrate feeding levels, the 30% protein ration resulted in a higher (although not significantly different) level of milk production (milk yield, fat yield and net energy in milk) and an increased level of liveweight gain ($p<0.05$) relative to the 17% protein ration. The importance of crude protein intake (RDP+UDP) was also confirmed in multiple regression analyses (significant partial regression coefficient) which related MEI and crude protein intake to net energy retention. The mechanism whereby protein had its effect was not clear. Digestibility may have been increased and/or ME may have been used more efficiently (possibly because more amino acids from the 30% protein ration should have been available at the tissue level). Unfortunately, the interpretation of this experiment was made difficult because differences in degradability and protein concentrations of supplements were confounded. The explanation of this has been previously given in Section 4.1.

4. From a practical point of view the concentrate supplementation was economic in all treatments. However, feeding the 17% CP at the high level (5.4 kgDM/cow daily) gave the highest marginal return.

5. Further investigations should study the importance of RDP supply in the ration (eg. by inclusion of urea at different levels).

4.3 GRAZING EXPERIMENT

The previous indoor experiment was carried out so that the pasture intake could be measured accurately from individual cows. The present grazing experiment was conducted to verify that the treatment effects observed on cut pasture were likely to occur on grazed pasture.

4.3.1 PRE-EXPERIMENTAL CONDITIONS

Following the indoor experiment, a further investigation was conducted for 3 weeks (24 Nov.- 16 Dec.1990), using some of the cows used in the previous trial, but grazing on pasture similar to that used in the preceding indoor experiment. Climatological data and background for the experimental site are the same as in the indoor experiment given in Appendices 1.1 and 2.1.

4.3.2 MATERIALS AND METHODS

4.3.2.1 Animals and Treatments

Three treatment groups from the indoor experiment were selected, viz. the pasture only (PF), the 17PH and the 30PL treatment. The reason for choosing the latter two treatments was to further examine the response when the cow consumed the same amount of crude protein but of different protein degradability. Unfortunately, there was not enough grazing area to compare all the previous 5 treatments therefore only three treatments were selected. The details of treatments are as follows:

Treatment 1. PF - Pasture only.
Treatment 2. 17PH - Pasture plus 6 kg of 17%CP (locally used concentrate).
Treatment 3. 30PL - Pasture plus 3 kg of 30%CP concentrate (low-degradable protein).

Description of the investigation has been summarised previously in Section 4.2.2.2.

4.3.2.2 Pastures and Supplements

The pastures and concentrates were the same as in the indoor experiment (See Section 4.2.2.2).

4.3.3 MEASUREMENTS

4.3.3.1 Feed Measurements

Before and after grazing, herbage mass was measured daily for 14 days. Herbage enclosed within three 1 m^2 (50cm x 200cm) quadrats were cut with a hand sickle at 15 cm above ground level for each treatment. They were then bulked and fresh weights were recorded. A subsample was taken for DM determination.

For the pregrazing herbage, a subsample of dried herbage (above 15 cm cutting height) bulked from each treatment within each paddock, was ground and analysed for N concentration (%) and *in vitro* digestibility (%).

Concentrates were individually fed to the supplemented cows in two equal meals during the morning and evening milking. The cows were allowed access to the concentrates for approximately an hour at each milking before they were turned out to the pastures. All cows ate all the concentrate given. Chemical composition of the concentrates, which are the same lots as used in the indoor experiment, was determined as in the indoor experiment (Section 4.2.3.1).

4.3.3.2 Animal Measurements

Over the period of 2 weeks, the animal measurements were the same as stated in the indoor experiment (Section 4.2.3.2).

4.3.4 STATISTICAL ANALYSIS

All data were analysed using the Statistic Analysis System (SAS) computing package (SAS Institute Inc., Cary, NC 27512-8000, USA. 1985,86,87) and the same model as given in the previous section (See Section 4.2.4).

4.3.5 RESULTS

4.3.5.1 Chemical Analysis of the Feeds

The chemical composition of the concentrates was the same as in the indoor experiment (Section 4.2.5.1, Table 4.2.3)

Chemical analyses of the pastures are given in Table 4.3.1)

Table 4.3.1 Chemical analyses of the pastures.

				in vitro				ME[2/]
	%DM	%CP	dg[1/]	%DMD	%OMD	%DOMD	%ASH	(MJ/ kgDM)
Grazed pasture								
Pd. 1	24.5	13.4	0.45	60.3	60.8	53.3	12.3	8.5
Pd. 2	23.4	13.9	0.42	61.7	61.4	54.5	11.2	8.7
Pd. 3	21.2	13.4	0.45	63.7	62.8	56.3	10.4	9.0
Pd. 4	25.9	13.1	0.47	62.5	61.9	55.3	10.7	8.8
Pd. 5	26.0	12.0	0.47	63.6	64.2	56.2	12.4	9.0
MEAN	**24.2**	**13.2**	**0.45**	**62.4**	**62.2**	**55.2**	**11.4**	**8.8**

1/ = Protein degradability after 12 h incubation (See Chapter 6).
2/ = ME = 0.16DOMD (MAFF, 1975).

4.3.5.2 Feed Intake and Sward Characteristics

4.3.5.2.1 Feed Intake

The daily pasture DM intake was calculated as the difference between the pre-grazing herbage mass and the residual herbage mass within a 24 hour break, divided by the number of animals grazing that break.

Mean values for allowance and apparent intake of pasture and concentrate DM, ME and CP in The Experimental Period II are presented in Table 4.3.2. These showed that there were no significant differences in allowances of DM, ME and CP between groups. However, total DM, ME and CP allowances of both the supplemented groups were significantly higher than the unsupplemented cows.

The cows eating the low protein concentrate (at 5.4 kgDM/cow daily, 17PH) ate less pasture DM ($p<0.05$) but ate more total DM ($p<0.001$) than the PF and 30PL (2.4 kg level) cows. The calculated substitution rates were 0.30 and 0.15 for the 17PH and 30PL cows respectively and this showed that the substitution rate increased with level of concentrate supplementation. Both the supplemented cows (17PH and 30PL) had higher values of total ME ($p<0.001$) and CP ($p<0.001$) intakes than the unsupplemented cows. However, the 17PH cows had a lower ME and CP intake from pasture than the PF and 30PL cows ($p<0.05$).

Table 4.3.2 Mean values for DM and ME allowance, and DM and ME intake of feeds in The Grazing Experimental Period.

	T1 PF	T2 17PH	T3 30PL	SEM	Sig.
DM allowance (kgDM/cow daily)					
As pasture	23.4	23.3	23.4	1.8	NS
As concentrate	-	5.4	2.6	-	-
Total	23.4^{b}	28.7^{a}	26.0^{ab}	1.8	*
DM intake (kgDM/cow daily)					
As pasture	12.2^{a}	10.6^{b}	11.8^{a}	0.6	*
As concentrate	-	5.4	2.6	-	-
Total	12.2^{c}	16.0^{a}	14.4^{b}	0.6	***
Substitution rate		0.30	0.15	-	-
ME allowance (MJ/cow daily)					
As pasture	206	205	206	15.7	NS
As concentrate	-	63	31	-	-
Total	206^{b}	268^{a}	237^{ab}	15.7	**
ME intake (MJ/cow daily)					
As pasture	107^{a}	93^{b}	104^{a}	5.0	*
As concentrate	-	63	31	-	-
Total	107^{c}	156^{a}	135^{b}	5.0	***
Crude protein allowance (g/cow daily)					
As pasture	3094	3079	3088	235	NS
As concentrate	-	913	744	-	-
Total	3094^{b}	3992^{a}	3832^{a}	235	**
Crude protein intake					
As pasture	1605^{a}	1397^{b}	1563^{a}	75	*
As concentrate	-	913	744	-	-
Total	1605^{b}	2310^{a}	2307^{a}	75	***

4.3.5.2.2 Sward Characteristics

The mean values of pregrazing herbage mass (HM) and residual herbage mass (RHM) are shown in Table 4.3.3. There were no significant differences in either pregrazing herbage mass (HM) or residual herbage mass (RHM) measured between treatments ($p>0.05$). However, there was a tendency towards higher values of RHM in both group of supplemented cows (950 and 813 vs 764 kgDM/ha).

Table 4.3.3 Mean values for pregrazing herbage mass (HM) and residual herbage mass (RHM) of the PF, 17PH and 30PL groups in The Experimental Period II (kgDM/ha, measured above 15 cm cutting height).

	T1 PF	T2 17PH	T3 30PL	SEM	Sig.
Pregrazing HM	2249	2240	2249	92	NS
Residual HM	764	950	813	111	NS

4.3.5.3 Animal Performance

The treatment mean values for milk yield, fat yield, fat concentration and liveweight change are presented in Table 4.3.4. These showed that the supplemented cows (17PH and 30PL) had higher values of milk and fat yields than the unsupplemented cows ($p<0.001$). Fat concentrations were similar ($p>0.05$). The unsupplemented cows had lower values of final liveweight and liveweight change than the supplemented cows ($p<0.01$ and 0.001 respectively).

Table 4.3.4 Mean values for yields of milk, milk fat, fat concentration, final liveweight and liveweight change in the Grazing Experiment.

	T1 PF	T2 17PH	T3 30PL	SEM	Sig.
Milk yield (kg/day)	5.8[b]	12.2[a]	11.1[a]	0.7	***
Fat yield (kg/day)	0.26[b]	0.50[a]	0.47[a]	0.03	***
Fat concentration (%)	4.19	4.09	4.38	0.18	NS
SNF yield (kg/day)	0.52	1.10	1.01	-	-
SNF concentration (%)	8.94	9.00	9.09	-	-
Final liveweight (kg)	366[b]	387[a]	387[a]	4.2	**
LW change (g/day)	-217[b]	87[a]	86[a]	78	***

The results shown are covariance adjusted means using the initial values before the start of the indoor experiment as covariates.

4.3.5.4 Overall relationships between nutrition and performance.

Assuming that the protein degradabilities of pasture and concentrates were as mentioned in Section 4.2.5.4, the estimated supply of RDP and UDP to the cows was calculated (Table 4.3.5). The resulting RDP/ME ratios in the rations consumed are also presented in Table 4.3.5. The ratios RDP/ME and the intakes of UDP increased progressively from treatment 1 (PF) through to 3 (30PL) and the high level of concentrate feeding also increased the RDP intake.

Table 4.3.5 The supply of rumen degradable protein (g/day, RDP), undegradable protein (g/day, UDP) and the ratio of RDP/MJ metabolisable energy intake (g/MJ), (Grazing Experiment).

Details:	PF	17PH	30PL
RDP supply[1/]			
As pasture	803	699	782
As concentrates	-	593	394
Total	803	1292	1176
UDP supply[1/]			
As pasture	802	698	781
As concentrates	-	320	350
Total	802	1018	1131
Total ME intake	107	156	135
RDP/ME intake	7.5	8.3	8.7

1/ Assuming protein degradability of pasture is 0.50 (Corbett *et al.*, 1987)
Protein degradability of concentrates were estimated from those values reported in Chapter 6.

By combining the data for milk yield and liveweight change (as MJ net energy), it was possible to examine the influence of supplementation on the apparent utilisation of metabolisable energy intake (Table 4.3.6). ME intakes were clearly increased by concentrate supplementation. The extent of the effect depended largely on level of feeding (See also Table 4.3.4). Although the 17PH cows consumed more ME than the 30PL cows ($p<0.001$), both groups of cows had similar values for net energy in milk, in liveweight gain and energy retention.

Table 4.3.6 The estimation of metabolisable energy requirement and utilisation (Grazing Experiment).

Details:	T1 PF	T2 17PH	T3 30PL	SEM	Sig.
(1) Total ME intake	107^{c}	156^{a}	135^{b}	5.0	***
(2) ME requirement for maintenance 1/	49	54	53	2.6	NS
(3) Net energy in milk 2/	24^{b}	46^{a}	42^{a}	2.6	***
(4) Net energy in LW 3/	-5^{b}	2^{a}	2^{a}	2.6	**
(5) Energy retention 4/	19^{b}	48^{a}	44^{a}	2.6	***
(6) MEI - ME_m 5/	58^{c}	102^{a}	82^{b}	5.0	***
(7) Efficiency 6/	0.33^{c}	0.47^{b}	0.54^{a}	0.03	***

1/ $ME_m = 0.60LW^{0.75}$
2/ From Equation 4 of Tyrrell and Reid (1965).
3/ 21.5 MJ/kg gain (ARC, 1980).
4/ (3) + (4).
5/ (1) - (2).
6/ (5) / (6).

4.3.5.5 Summary of the Results

1. As with the indoor experiment, herbage DM intake was decreased by concentrate supplementation (0.15 and 0.30 kg/kg concentrate DM consumed by the 30PL and 17PH cows respectively).
2. Yields of milk and milk fat were increased by concentrate supplementation.
3. Liveweight was also increased by concentrate supplementation.
4. Of importance, the results in this grazing experiment were largely dependent on the previous indoor experiment.

4.3.6 DISCUSSION

4.3.6.1 Effect of Concentrate Supplementation on Herbage Intake

In the present experiment, herbage intake was estimated by a sward cutting technique which also provides information on the herbage mass and allowance. The sward cutting technique had another advantage which was that the measurement technique was unaffected by concentrate supplementation, in contrast to methods based on indigestible markers (Milne *et al.*, 1981). The major disadvantages of the technique were that it estimated only mean intakes for groups of cows (in the case of group grazing as in the present study) and the labour input was high. In the present study, cutting height was 15 cm above ground level. The selection of this relatively high cutting height was necessary to avoid damaging the elevated growing points of the grass species when cutting or grazing. Such a requirement is particularly important for many erect tropical grasses, especially Guinea grass, as defoliation below 12 to 15 cm can lead to significant tiller death (B.R. Watkin, Personal Communication, unpublished data).

However, the accuracy of herbage intake measurements of grazing animals, using this technique, can be seriously affected by cows grazing well below this cutting level, if not carefully attended and controlled. Furthermore, there can be considerable error in the pasture sampling method and in the variability between samples (Le Du and Penning, 1982).

The crude protein concentration of grazed pasture was slightly higher than the cut pasture used in the previous indoor experiment. This possibly reflected the difference in sampling methods, as the cut pasture was sampled from pasture cut with a double-chopped harvester while the grazed pasture was cut with a hand sickle. The pasture cut by harvester was possibly contaminated by dead material picked up by the machine. However, the two pastures were similar in *in vitro* dry matter digestibility.

Pregrazing herbage mass, herbage allowance and herbage digestibility can affect intake of herbage by grazing dairy cows. With animals grazing temperate pasture, increases in herbage intake were observed with increasing herbage mass (Hodgson, 1975; Combellas and Hodgson, 1979; Jamieson and Hodgson, 1979; Stockdale and King, 1983; Zoby and Holmes, 1983; Forbes and Hodgson, 1985; Stockdale, 1985), herbage allowance (Le Du *et al.*, 1979; Bryant, 1980; Glassey *et al.*, 1980; King and Stockdale, 1984; Stockdale, 1985), and herbage digestibility (Hodgson, 1977). An increase in herbage intake with increasing herbage mass has been also reported when cows grazed on tropical pasture (Combellas *et al.*, 1979). However, many examples have shown the relationship between herbage intake and herbage mass (Hodgson, 1977; Combellas and Hodgson, 1979; Hodgson and Jamieson, 1981; Meijs, 1982), or herbage allowance (Combellas and Hodgson, 1979; Bryant, 1980) to be asymptotic.

The unsupplemented cows in the present study consumed a relatively high pasture intake (12.2 kgDM/cow daily) for tropical pastures of 61% DMD compared with cows grazing on temperate pastures (Hodgson, 1977). As previously been discussed (See Section 4.2.6.1), at this DMD (60%), the voluntary intake of tropical pastures has been shown to be 20% greater than of temperate pastures (Minson, 1980).

Grazing trials with lactating cows in early lactation have shown that concentrate feeding reduced herbage consumption in temperate pasture (Jennings and Holmes, 1984; Meijs and Hoekstra, 1984; Meijs, 1986), with substitution rates between 0.03 and 0.79 kgDM/ kg concentrate DM eaten. The variation in substitution rates could be explained by differences in herbage digestibility, levels of concentrate feeding and restricted access to herbage causing low herbage intake. Leaver *et al.* (1969) reported a substitution rate of 0.55 kg of herbage OM/kg concentrate OM consumed at restricted grazing with dairy cows. Meijs and Hoekstra (1984) suggested that the effect of concentrate feeding on herbage intake of grazing cows depends on the level of herbage allowance. The substitution rates found in the present study were 0.15 and 0.30 kgDM/kgDM concentrate for the 30PL and 17PH cows respectively. These are in the range reported in the literature reviewed.

The present experiment showed an increased substitution rate with the increased level of concentrate feeding. Increases in substitution rates with increasing levels of concentrate consumption have been reported in dry cows (Sarker and Holmes, 1974) and lactating cows (Stockdale and Trigg, 1985), although Meijs and Hoekstra (1984) did not found this relationship.

In the present study, residual herbage mass was increased by concentrate feeding although the increases (49 and 186 kgDM/ha for the low and high level of concentrate intake) were not statistically significant. The lack of a significant effect of concentrate feeding on residual herbage mass was presumably because of the large variation of residual herbage mass estimated between paddocks (i.e. large standard error of the mean).

Since residual herbage mass is the consequence of the difference between pregrazing herbage mass and herbage intake, increases in residual herbage mass were presumably caused by reductions in herbage intake due to concentrate supplementation. This effect of supplementation on residual herbage mass had been observed by several workers (Stockdale and Trigg, 1985; Stakelum, 1986a; Grainger, 1987).

4.3.6.2 Effect of Concentrate Supplementation on Animal Performance

Yields of milk and milk fat in all treatments were improved compared to the indoor experiment but seemed to show the same trend between the treatments. The improved yields were probably due to the selective grazing of the animal consuming the more nutritious parts of the pasture on offer compared to the lack of selection possible on the 'cut-and-carry' pasture used indoors.

Concentrate supplementation increased yields of milk and milk fat in the present study. The mean responses to 1 kgDM concentrate consumption were 1.1 and 2.0 kg milk in the 17PH and 30PL groups respectively, which were higher than those reported by Leaver *et al.* (1968) and Journet and Demarquilly (1979) in the temperate zones, and by Jennings and Holmes (1985) in the tropics. The relatively high responses in yields in the present study were probably due to the fact that the PF cows received low

quality pastures and low supply of RDP relative to metabolisable energy intake (7.5 gRDP/MJME; Table 4.3.5) leading to a reduced microbial protein synthesis (ARC, 1984). Consequently, the milk yield of unsupplemented cows was suppressed and much lower than would have been expected from the apparent ME intake probably due to limitations imposed by RDP supply and lower than that reported by Lekchom *et al* (1989) from cows fed pasture only at the Dairy Farming Promotion Organisation of Thailand (DPO).

Alternatively and as in the indoor experiment, the low supply of RDP in the unsupplemented cows may have led to reduced fermentation of organic matter in the rumen. This may have caused an overestimate of ME intake in the unsupplemented cows. The unlikely low calculated "apparent efficiency of ME utilisation above maintenance" of 0.33 probably reflected the overestimate of ME intake by the unsupplemented cows. It should be realised that an error in estimated ME intake would result in a difference in calculated apparent efficiency of ME utilisation. The simple calculation has been shown previously in Section 4.2.6.2.

In addition, the results of the grazing experiment may have been influenced by carry-over effects from the indoor experiment - as the pre-experimental period of 1 week only may have been inadequate. However, when the response was calculated between the supplemented cows (17PH and 30PL) the response was 0.39 kg milk per kg of extra concentrate DM eaten, which was similar to the indoor experiment and other published works (Leaver *et al.*, 1968; Journet Demarquilly, 1979; Jennings and Holmes, 1985) and similar to another experiment carried out at the same site as the present study (Lekchom *et al.*, 1989).

Care must be taken when expressing the responses of milk yield to kgDM concentrate consumed. As has previously been discussed in Section 4.2.6.2 (indoor experiment), the responses calculated from 0 to some kgDM concentrate eaten often resulted in higher values than when calculated from extra concentrate DM eaten (some to more DM concentrate eaten).

Considering the supply of nutrients in terms of either energy or protein, the 17PH and 30PL cows had higher energy (156 and 135 MJ/cow daily respectively; $p<0.001$) and crude protein (2310 and 2307 g/cow daily respectively; $p<0.001$) intakes than the PF cows (107 MJ and 1605 g/cow daily). This resulted in much higher milk yield in the 17PH and 30PL cows than the PF cows. When comparisons were made between the supplemented cows, the 17PH and 30PL cows had similar crude protein intakes (2310 and 2307 g/cow daily respectively) but different ME intakes (156 and 135 MJME/cow daily respectively). Despite a higher ME intake, the 17PH cows produced only slightly more milk than the 30PL cows (12.2 and 11.1 kg/cow daily respectively). This was probably due to the higher supply of UDP in the 30PL group and thus higher amino acids reaching the intestine, enhancing the apparent efficiency of ME utilisation for milk production, in the 30PL cows compared to the 17PH cows (1131 and 1018 g/cow daily respectively). Increases in milk yield have been observed in association with increases in supply of UDP (Orskov *et al.*, 1977; 1981; Stobbs *et al.*, 1977; MacRae, 1983).

4.3.6.3 Overall relationships between nutrition and performance

The PF cows had a lower ratio of RDP/ME than the 17PH and 30PL cows (Table 4.3.5), and lower than that suggested by ARC (1984) i.e. 7.5 compared to 8.3, 8.7 and 8.1 g/MJ for the 17PH, 30PL and ARC (1984) respectively. Although the 17PH and 30PL cows had slightly higher values for RDP/ME than ARC (1984), this could not explain the slightly higher milk yield in the 17PH cows than the 30PL cows.

In the present study, the 30PL cows consumed less ME and RDP but more UDP while the 17PH cows received more ME and RDP but less UDP (both groups had similar CP intake). The extra 20 MJME available for milk production (after accounting for liveweight gain) of the 17PH cows over the 30PL cows should have been resulted in approximately extra 4 kg of milk produced. In fact, only a small increase of 1 kg extra milk was observed in favour of the 17PH cows. This is possibly due to higher amino acids supply to the 30PL cows than the 17PH cows as seen by higher intake of UDP. Increases in postruminal amino acid absorption by increased UDP supplementation have been found to increase milk yield through the more efficient use of absorbed energy (Miller, 1982).

The improved efficiency of energy utilisation in the 30PL group was shown by the higher 'apparent efficiency of energy utilisation' above maintenance compared to the 17PH group (0.54 and 0.47 respectively; Table 4.3.6). The results also showed the same trend as in the indoor experiment. The 'apparent efficiency of energy utilisation' above maintenance by the PF cows was higher than in the indoor experiment but still very low; as possible reasons were discussed previously in the indoor experiment (Sections 4.2.6.3 and 4.3.6.2).

4.3.6.4 An economic assessment of marginal financial returns

An economic assessment of the marginal returns from the milk produced per treatment less the cost of the concentrate was made (Table 4.3.7). It showed that the marginal return to concentrate was higher in the 17PH group than in the 30PL group, confirming the results obtained in the previous indoor experiment. However, there is an optimum level of feeding above which little or no response will be obtained. At the same site as the present study, where grazing dairy cows were supplemented with varying amounts of concentrates (0, 3, 6, 8, 13 and *ad libitum* kgDM/cow daily), Lekchom *et al.* (1989) reported a linear response up to a maximum of 13 kgDM/cow daily (asymptote) of concentrate, but in terms of financial return the feeding of 6 kgDM/cow daily of concentrate gave the highest financial return. High concentrate feeding levels will reduce herbage intake, whereas feeding low levels of high protein concentrate can result in similar milk yield to feeding twice the quantity of low protein concentrate. Clearly, with the present price of milk and cost of concentrates, there is no justification for Thai farmers to feed an expensive high protein concentrate (e.g. 30% CP) to their milking cows as the lower, commonly used quality of concentrate (17% CP) when fed at adequate levels (e.g. 6 kg/cow daily) can achieve greater profit.

Table 4.3.7 Marginal return from concentrate supplementation.

Details:	T1 PF	T2 17PH	T3 30PL
Milk yield (kg/cow daily)	5.8	12.2	11.1
Milk return (NZ$)[1/]	3.19	+3.52	+2.91
Cost of concentrate (NZ$)[2/]	0.00	+1.23	+0.94
Marginal return (NZ$)	-	2.29	1.97

1/ NZ$ 0.55 /kg milk.
2/ NZ$ 0.22 (17%CP); 0.36 (30%CP).

4.3.7 CONCLUSION

1. The grazing experiment shows the same results as the indoor experiment i.e. concentrate supplementation increased milk yield due to increased total ME intake.

2. It is clear from the present study that the main effect contributing to differences in animal performance was the increased ME intake which was caused by the feeding of concentrates. There is also a suggestion that the milk yield of cows receiving the 30% CP concentrate at low level was relatively high compared with the ME intake due possibly to the increased supply of postruminal absorption of amino acids compared to cows receiving the 17% CP concentrate at high level. However, the high protein concentrate was more expensive than the low protein concentrate. Greater profits can be achieved by feeding a moderate level (e.g. 6 kgDM/cow daily) of the low protein (17% CP) concentrate.

3. Between the supplemented groups, the high protein concentrate ration resulted in similar net energy in milk, net energy in liveweight and net energy retention despite a lower ME available above maintenance and perhaps because a higher efficiency of use of energy.

4. From a practical point of view, although the low level of high protein concentrate resulted in slightly lower milk yield than the high level of low protein concentrate, the marginal response was still profitable.

CHAPTER 5

THE EFFECT OF PROTEIN DEGRADABILITY IN CONCENTRATE SUPPLEMENT ON DAIRY COW PERFORMANCE IN EARLY LACTATION FED ON TROPICAL GRASS SILAGE IN THAILAND

5.1 INTRODUCTION AND OBJECTIVES

The experiment was originally intended to confirm and extend the results from the previous study undertaken in Thailand (Chapter 4), on fresh pasture. In the original study and in the sheep study (Chapter 7) the amount of rumen degradable protein (RDP) and undegradable protein (UDP) available in the diet appeared to be important in determining performance. Thus the first objective was to study the effect of RDP concentration in concentrates for lactating cows by varying the amount of urea in the concentrates. Also it was thought to be important to compare RDP from plant protein (which provides amino acids in rumen fluid) with RDP from urea (which provides ammonia). Unfortunately, due to an unusual dry period in July/August, fresh forage was not available so that silage had to be used as the roughage part of the ration. However, the objectives of the experiment remained as planned.

The grazing season in Thailand occurs between May and October of each year. During the remainder of the year forage growth is severely restricted by lack of rainfall, unless irrigation is feasible. Therefore surplus pasture during the rainy season is conserved as silage or hay and used during the dry season.

It is well established that the intake of silage is generally lower than that of the original fresh pasture or as hay (Moore *et al.*, 1960; Harris and Raymond, 1963). However, the extent of this depression varies greatly and generally reflects the degree of chemical change that occurs during ensiling. Several of the end products of fermentation, for example acids or nitrogenous compounds, have been suggested to be responsible for this reduction in silage quality (Wilkins *et al.*, 1978; Gill *et al.*, 1988), although attempts to relate intake to the concentrations of these materials have produced variable results.

To overcome the deficiencies of silage it is necessary to supplement the diet with concentrate and much research effort has been expended on studies of the composition of supplements. Results often show high rates of substitution between concentrate and silage, and attempts to reduce substitution by the inclusion of fibre based supplements have not produced consistent results (Thomas *et al.*, 1986).

There has been considerable research effort to measure the responses in milk production to concentrate feeding of cows given silage. In a review of published data, Thomas (1980) reported a value of 0.79 kg (solids corrected) milk per kg additional concentrate (DM) but noted a wide variation in response. Much larger responses were observed recently by Rae *et al.*(1986) who noted values of 1.3 and 3.5 kg milk per kg additional cereal concentrate DM and per kgDM fish meal/soyabean mixture (low protein degradability) respectively. The higher response to these protein-rich concentrates reflected the increase in silage DM intake compared with reduced DM intake when the cereal concentrate was fed.

In many of the trials, increasing the proportion of protein in the concentrate has resulted in an increase in silage digestibility and in silage intake (Oldham *et al.*, 1985; Thomas *et al.*, 1985). Recently there has been much research interest in the use of supplements containing proteins which are more resistant to degradation in the rumen (Miller *et al.*, 1983; Small and Gordon, 1985). Rae *et al.*(1986) used lactating cows supplemented with a mixture of fish meal and soyabean and found that cows consumed 0.5 kgDM more silage per kgDM additional supplement than the unsupplemented control cows. In the same experiment, when a cereal concentrate was used supplemented cows consumed 0.23 kgDM less silage per kgDM of additional supplement than the control cows. The intake of silage by the control cows was 11.4 kgDM. This experiment confirmed the early work of Castle and Watson (1976) who reported similar responses.

The present study aimed to investigate the effect of concentrates containing crude protein of different degradabilities (altered by inclusion of 0, 1 and 2% urea) on the intake of silage and on animal performance. In addition, the fourth treatment was provided with extra RDP from plant protein rather than urea.

5.2 MATERIALS AND METHODS

The experiment was conducted at Dairy Farming Promotion Organisation of Thailand (D.P.O.), Muak Lek, Saraburi, Thailand, for 9 weeks during 19 January - 22 March 1992. Background details of experimental site was given in Appendix 2.1.

5.2.1 PRE-EXPERIMENTAL CONDITIONS

5.2.1.1 Animals and Treatments

36 crossbred dairy cows (62.5 - 75% Holstein Friesian or Red Danish crossed with local *Bos indicus* breed), in their first 3 months of lactation) were randomly assigned into 4 treatment groups, each with a different concentrate fed as supplement.

Concentrate 1. Contained 19% protein with a low (0.55) degradability (and no urea).

Concentrate 2. Concentrate 1, but with 1% urea.

Concentrate 3. Concentrate 1, but with 2% urea.

Concentrate 4. Contained 19% protein with a high (0.65) degradability (and no urea).

All cows were given grass silage (details are given in Section 5.2.1.3) as a basal diet and were supplemented with 4.5 kgDM concentrates per cow daily. Details of the cows used in this experiment are given in Table 5.2.1.

Table 5.2.1 Data for cows immediately prior to the start of the experiment.

	Concentrates			
Mean values for	1	2	3	4
No. of cows	9	9	9	9
Days in lactation	72±5	75±6	74±4	76±6
Milk yield (kg/d)	12.2±0.9	12.1±0.8	12.4±0.8	12.3±0.9
Fat yield (g/d)	500±45	501±35	517±38	485±35
Protein yield (g/d)	347±26	326±19	356±25	341±23
Fat conc. (%)	4.07±0.17	4.15±0.11	4.14±0.14	3.93±0.14
Protein conc. (%)	2.84±0.10	2.72±0.06	2.87±0.13	2.77±0.08
Liveweight (kg)	389±25	381±10	372±14	388±11

Data shown are means ± SE.

5.2.1.2 Management and Feeding of the Animals

Before the start of the experiment cows were housed in individual stalls and fed generously on grass silage as a basal diet and supplemented with locally used concentrates containing 17% crude protein, including 2% urea at approximately 6 kgDM/cow daily. During this 2 week period, data were recorded and were later used as covariates. The experimental concentrates were gradually introduced according to the treatment groups until the commonly used concentrates had been completely replaced by the experimental concentrates, at 4.5 kgDM concentrates per cow daily. All cows were allowed 20 days for adjustment to the new concentrates and data were collected over the next 5 weeks.

Concentrate supplements were individually offered twice daily at 0500 and 1500 h. Grass silage was given *ad libitum* twice daily at 0600 and 1600 h.

5.2.1.3 Silages and Concentrates

The silage, which was from one silo, was made from Guinea grass (*Panicum maximum*) and Ruzi grass (*Bachiaria ruziziensis*) pastures which had been closed for 40-50 days prior to ensiling and hence was rather over mature at cutting. The pasture was cut by a Double-chop harvester and blown directly to the trailer without wilting. It was then compacted in a trench silo with walls and floor of concrete. The compacted pasture in the silo was covered with polythene sheet weighted down with a complete covering of soil.

Concentrates used in the present study comprised mainly local feedstuffs. Prior to these formulations, each ingredient was analysed for its concentration of DM, N and the degradability of its protein (Results have been reported in Chapter 6). The concentrates also differed in their concentrations of urea, according to treatment, and consequently in the degradabilities of their protein. Details of ingredients used in the concentrates are given in Table 5.2.2.

Table 5.2.2 The formulation of concentrates used (per 1000 kgDM).

	Concentrates			
Composition	1	2	3	4
Rice bran	340	380	430	550
Cotton seed meal	270	190	100	20
Palm meal	180	180	180	60
Maize	80	110	140	40
Groundnut meal	50	50	50	250
Molasses	50	50	50	50
Minerals	30	30	30	30
Urea	-	10	20	-

5.3 MEASUREMENTS

5.3.1 FEED MEASUREMENTS

Both the quantities of silage and concentrates offered and left uneaten were weighed twice daily at feeding time for 4 days/week. The samples of silage offered and refused were taken twice daily (morning and evening feeding) and dried at 70-80°C for 24 hrs for DM determination. A dried subsample of silage offered (bulked from each week) was kept for chemical analyses.

Each concentrate was sampled on 2 occasions when it was mixed. The samples were dried at 70-80°C for 24 hrs and kept for chemical analyses.

5.3.2 ANIMAL MEASUREMENTS

5.3.2.1 Liveweight

Cows were weighed on two consecutive days following morning milking immediately prior to the start and at the end of the experiment. The liveweight change was defined as the difference in liveweight between the start and the end of the experiment.

5.3.2.2 Milk Production and Composition

Throughout the experiment, individual morning and evening milk yields were recorded daily. Milk samples were taken on two consecutive days each week for analysis of milk fat and milk protein using a Milkoscan 140 A/B analyser (Foss electric, Denmark). Unfortunately, this machine was not standardised for lactose analysis therefore the lactose concentration could not be obtained.

5.4 STATISTICAL ANALYSIS

All data were analysed using the Statistical Analysis System (SAS) computing package (SAS institute Inc., Cary, NC 27512-8000, USA., 1986,86,87).

Milk yield, fat yield, protein yield and their concentration were analysed using the repeated measurement of covariance (Gill and Hafs, 1971; Finn, 1974; Morrison, 1976; Bryant and Gillings, 1985). See Appendix 4.3. The data recorded during the experimental period were subjected to covariance analyses, using the yields for individual cows recorded before the start of the experiment as covariates.

Silage intake and liveweight change were analysed using analysis of variance (Steel and Torrie, 1986). See Appendix 4.1.

Final liveweight was analysed using analysis of covariance (Steel and Torrie, 1986) with preexperimental liveweight as covariate. See Appendix 4.2.

Relationships between individual animal performance and ration intake attributes (MEI, RDP and UDP) were examined using stepwise multiple regression analyses after covariance adjustment. A variable was included in a regression only if it added significantly ($p<0.05$) to the model.

5.5 RESULTS

5.5.1 CHEMICAL ANALYSIS OF FEEDS

The chemical compositions of the concentrates are shown in Table 5.5.1. Chemical analysis of the concentrates actually used in the present study showed that the intended level of 19% crude protein in the Concentrates 1 and 4 was achieved. The variation in protein degradability by inclusion of urea was also achieved. The Concentrates 2 and 3 had higher crude protein concentration because of the inclusion of urea.

Table 5.5.1 The chemical composition of concentrates used.

Component	Concentrates			
	1	2	3	4
Dry matter (%)	90.6	90.6	90.4	90.4
Crude protein (%)	18.9	22.6	21.5	19.5
Ash (%)	15.6	14.0	14.8	13.7
In vitro				
Dry matter digestibility (%)	62.0	63.6	63.5	66.8
Organic matter digestibility (%)	70.3	71.6	71.6	73.8
Digestible organic matter in the dry matter (%)	58.3	60.5	60.2	63.2
Neutral detergent fibre (%)	50.8	51.0	49.7	51.5
Acid detergent fibre (%)	32.0	30.2	28.1	29.3
Hemicellulose (%)	18.8	20.9	21.6	22.1
Cellulose (%)	23.1	21.3	20.3	21.8
Lignin (%)	8.9	8.9	7.8	7.5
Estimated metabolisable energy (MJ/kgDM)[1/]	9.3	9.7	9.6	10.1
Estimated protein degradability (%)[2/]	0.57	0.63	0.68	0.62

1/ ME = 0.16DOMD (MAFF, 1975).

2/ Estimated from results obtained from Chapter 6.

The chemical analyses of silage used in this experiment are shown in Table 5.5.2 with these values being toluene-corrected (Barber *et al.*, 1984). This showed that the quality of the silage used was very low. The average crude protein concentration was only 5.2% and the mean *in vitro* dry matter digestibility was only 47.9%. This is probably typical of much of the silage made in Thailand from over-mature pasture. The estimated metabolisable energy concentration was on average 8.2 MJ/kgDM and protein degradability 0.60.

Table 5.5.2 The chemical composition of silage.

Component	Weeks						Mean
	1	2	3	4	5	6	
Dry matter (%)[1/]	25.6	26.2	26.8	26.3	26.7	26.4	**26.3**
Crude protein (%)[2/]	5.0	5.1	5.4	5.0	5.3	5.2	**5.2**
Ash (%)[2/]	7.6	8.8	10.0	10.4	10.1	11.9	**9.8**
In vitro							
Dry matter digestibility (%)[3/]	47.2	45.4	48.4	47.5	49.6	49.0	**47.9**
Organic matter digestibility (%)[3/]	52.9	51.4	52.9	52.7	53.8	53.1	**52.8**
Digestible organic matter in the dry matter (%)[3/]	51.9	49.8	51.3	50.9	52.2	51.0	**51.2**
Neutral detergent fibre (%)[2/]	69.6	70.4	67.8	68.1	67.3	70.3	**68.9**
Acid detergent fibre (%)[2/]	38.4	43.1	42.3	40.6	42.4	46.9	**42.3**
Hemicellulose (%)[2/]	31.2	27.3	25.5	27.5	24.9	23.4	**26.6**
Cellulose (%)[2/]	32.9	36.5	36.9	35.6	36.8	41.2	**36.7**
Lignin (%)[2/]	5.5	6.6	5.4	5.0	5.6	5.7	**5.6**
Estimated metabolisable[4/] energy (MJ/kgDM)	8.3	8.0	8.2	8.1	8.3	8.2	**8.2**
Estimated protein degradability[5/]	0.59	0.60	0.62	0.59	0.61	0.60	**0.60**

The values shown are adjusted for oven DM as follows: (Barber *et al.*, 1984).

[1/]Corrected Toluene DM (%) = Oven DM (%) + 2.3%

[2/]Corrected CP (%) = $\frac{\text{CP (\%) x Oven DM (\%)}}{\text{Corrected DM (\%)}}$

[3/]Corrected DOMD (%) = $100 - \frac{(100 - \text{DOMD \%}) \text{ x Oven DM}}{\text{Corrected DM (\%)}}$

[4/] = ME = 0.16DOMD (MAFF, 1975)

[5/] = dg = (CP - 22.5)/CP; where: CP = g crude protein/kgDM (Webster *et al.* 1982).

Table 5.5.3 Mean values for feed dry matter offered and eaten (kgDM/cow daily), feed metabolisable energy offered and eaten (MJ/cow daily), feed crude protein offered and eaten (g/cow daily).

Mean values for:	Concentrates 1	2	3	4	SEM	Sig.
Feed dry matter offered						
As silage	17.5	17.5	17.5	17.5	-	-
As concentrates	4.5	4.5	4.5	4.5	-	-
Total	22.0	22.0	22.0	22.0	-	-
Feed dry matter eaten						
As silage	8.8^{ab}	9.1^{a}	8.4^{b}	8.5^{b}	0.2	**
As concentrate	4.5	4.5	4.5	4.5	-	-
Total	13.3^{ab}	13.6^{a}	12.9^{b}	13.0^{b}	0.2	**
Feed ME offered						
As silage	143	143	143	143	-	-
As concentrates	42	44	43	45	-	-
Total	185	187	186	188	-	-
Feed ME eaten						
As silage	72^{ab}	75^{a}	69^{b}	69^{b}	1.7	**
As concentrate	42	44	43	45	-	-
Total	114^{b}	119^{a}	112^{b}	114^{b}	1.7	**
Feed CP offered						
As silage	910	910	910	910	-	-
As concentrates	851	1017	968	878	-	-
Total	1761	1927	1878	1788	-	-
Feed CP eaten						
As silage	460^{ab}	474^{a}	438^{b}	441^{b}	10.9	**
As concentrate	851	1017	968	878	-	-
Total	1311^{c}	1491^{a}	1406^{b}	1318^{c}	10.8	***
Crude protein concentration in total ration (%)	9.9	11.0	10.9	10.1	-	-
Metabolisable energy concentration in total ration (MJ/kgDM)	8.6	8.8	8.7	8.8	-	-

5.5.2 FEED INTAKE

Feed dry matter (DM), metabolisable energy (ME) and crude protein (CP) offered, both as silage and concentrates, as well as total DM, ME and CP consumed are presented in Table 5.5.3.

The cows on Concentrate 2 had higher ($p<0.01$) intakes of silage DM , total DM, silage ME, and silage CP than the cows given Concentrates 3 and 4. The cows on Concentrates 1, 3 and 4 had lower values of total ME and CP intakes than the cows on Concentrate 2 ($p<0.01$).

The concentrations of crude protein in the total ration eaten by cows in each group are also given in Table 5.5.3 and all fell within a fairly narrow range (10.4-11.6%).

Statistical analyses of values based on toluene-corrected and non-corrected oven dry matter data showed no difference in terms of treatment effects.

5.5.3 ANIMAL PERFORMANCE

Mean values for yields of milk, fat and protein, and milk composition are presented in Table 5.5.4. These showed that the cows receiving Concentrate 2 produced higher yields of milk and protein than the other groups ($p<0.001$ and 0.001 respectively). However, no significant difference in fat yield between treatments was observed. The cows on Concentrate 2 had a lower ($p<0.05$) fat concentration in their milk compared with the other cows whereas the protein concentrations were similar for all treatments.

Figures 5.1 to 5.5 show the effect of different concentrate supplementation on yields of milk, milk fat and milk protein, and concentrations of milk fat and milk protein.

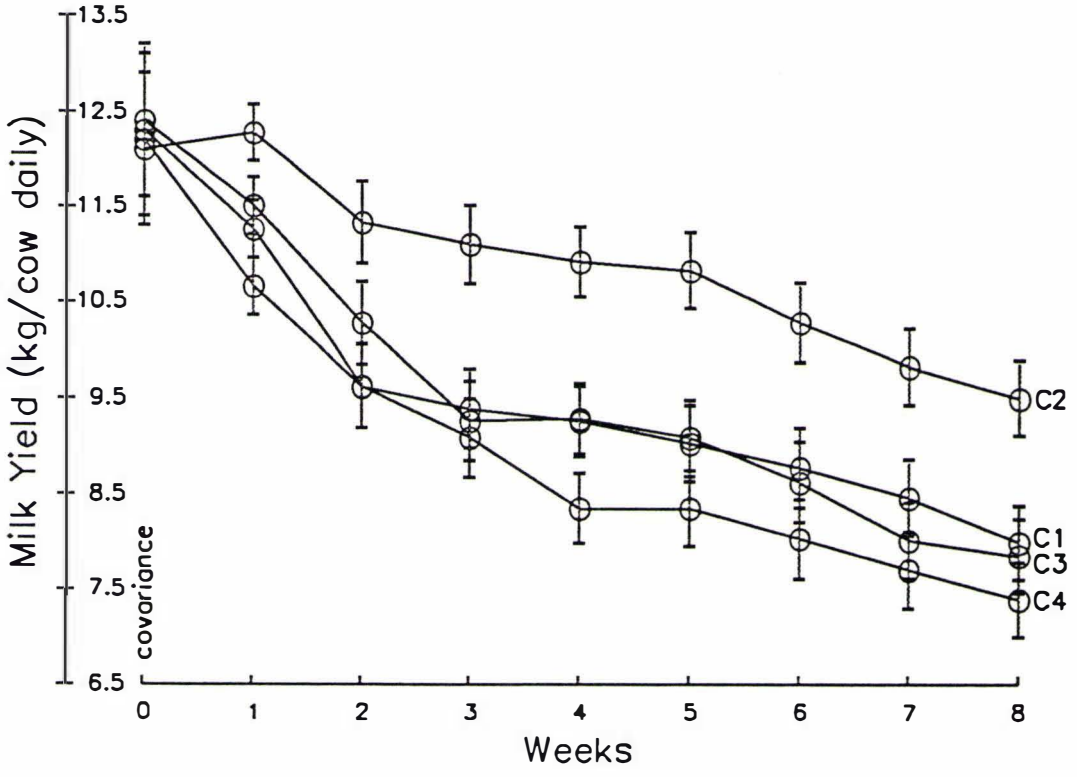

Figure 5.1 The effect of concentrates which differed in degradabilities of their proteins on milk yield over the experimental period. Vertical bars indicate standard error of least square means.

C1 = Concentrate contained 19% crude protein with a low (0.55) degradability (and no urea).

C2 = As C1, but with 1% urea.

C3 = As C1, but with 2% urea.

C4 = Concentrate contained 19% crude protein with a high (0.65) degradability (and no urea).

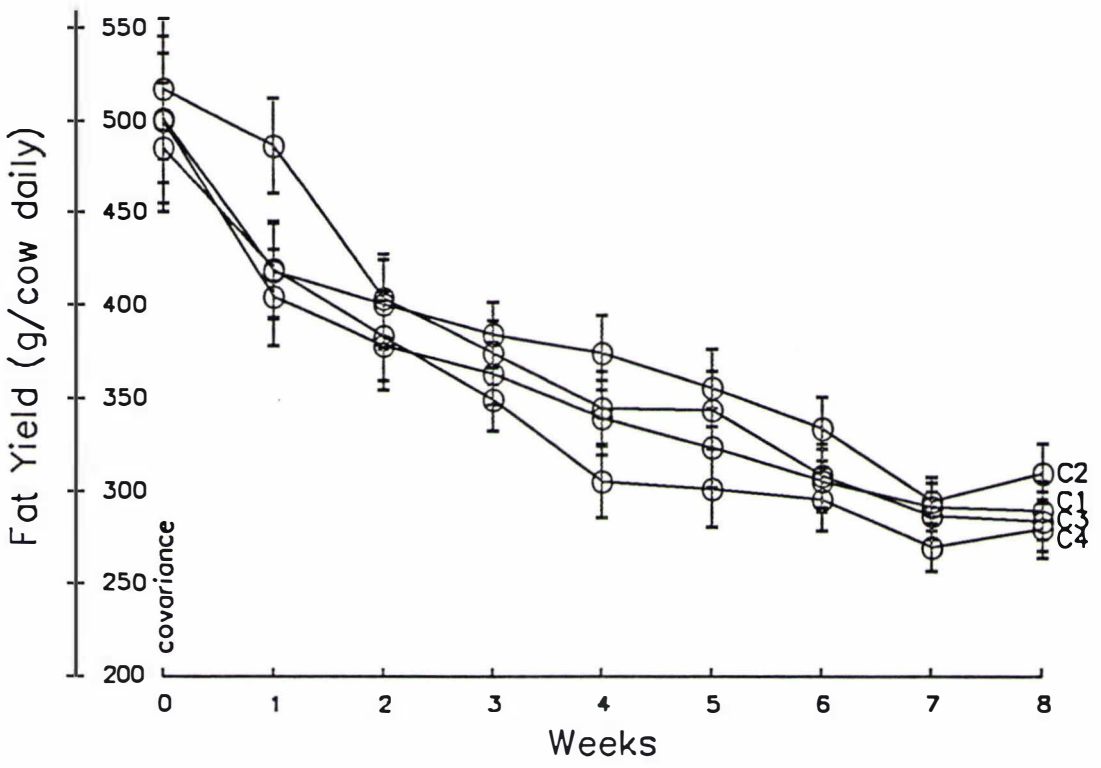

Figure 5.2 The effect of concentrates which differed in degradabilities of their proteins on milk fat yield over the experimental period. Vertical bars indicate standard error of least square means. Abbreviations as in Figure 5.1.

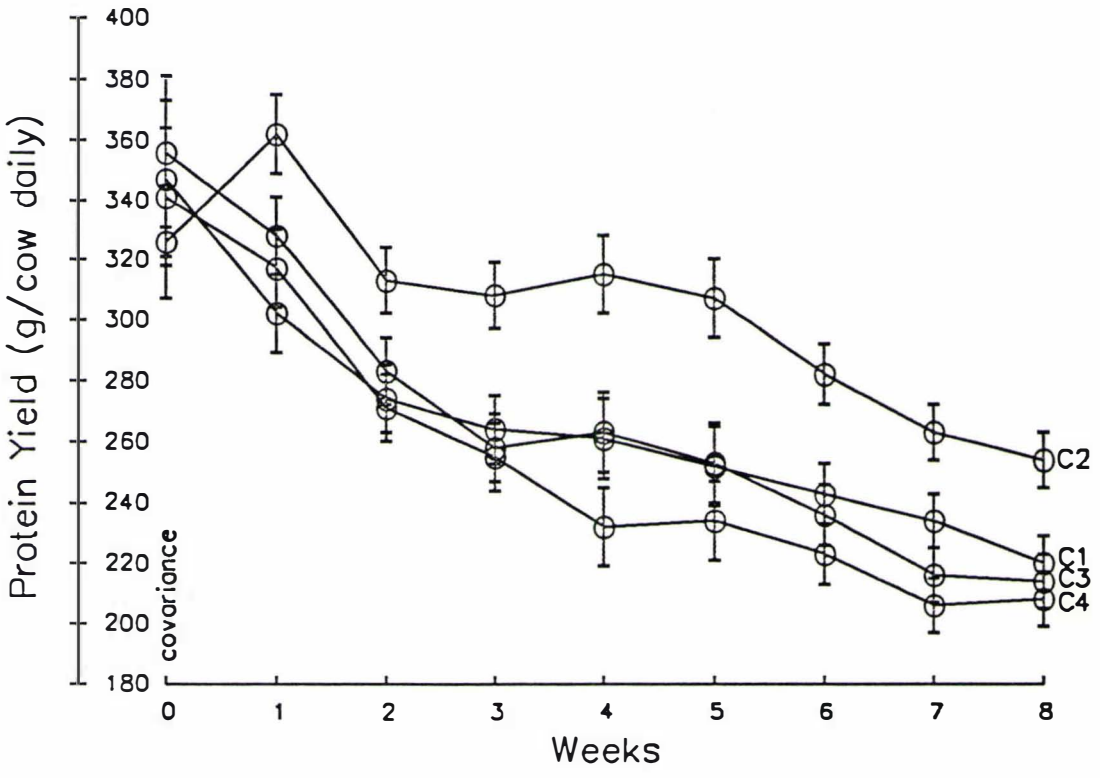

Figure 5.3 The effect of concentrates which differed in degradabilities of their proteins on milk protein yield over the experimental period. Vertical bars indicate standard error of least square means. Abbreviations as in Figure 5.1.

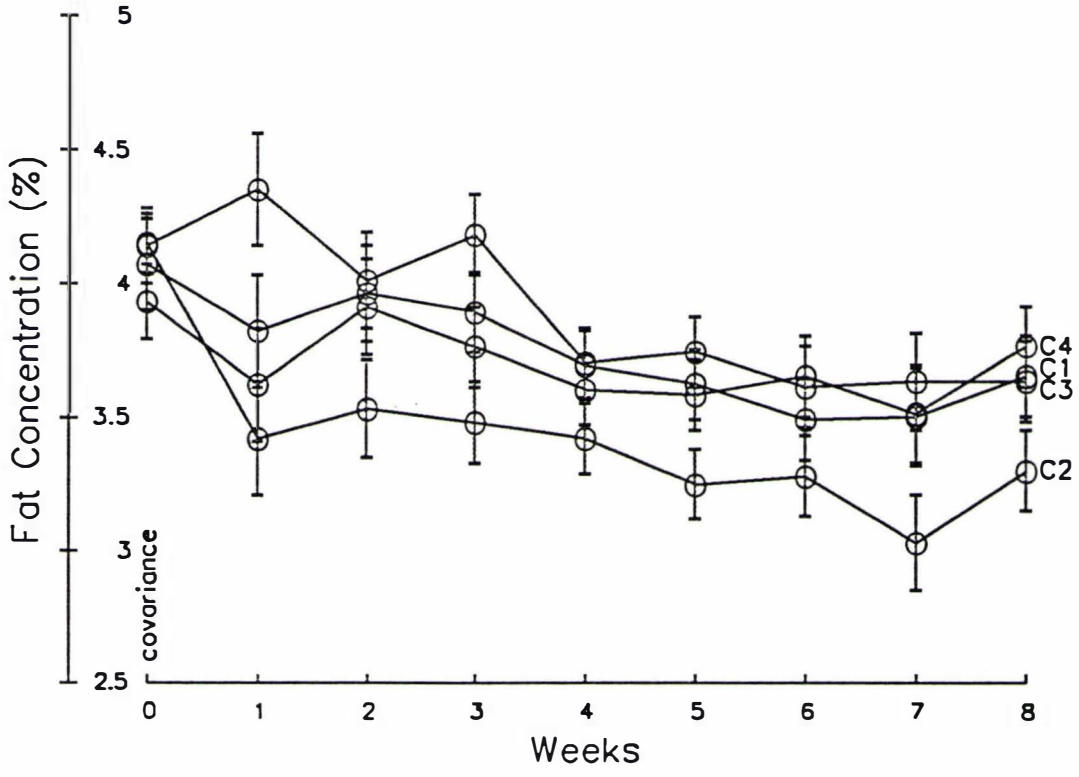

Figure 5.4 The effect of concentrates which differed in degradabilities of their proteins on milk fat concentration over the experimental period. Vertical bars indicate standard error of least square means. Abbreviations as in Figure 5.1.

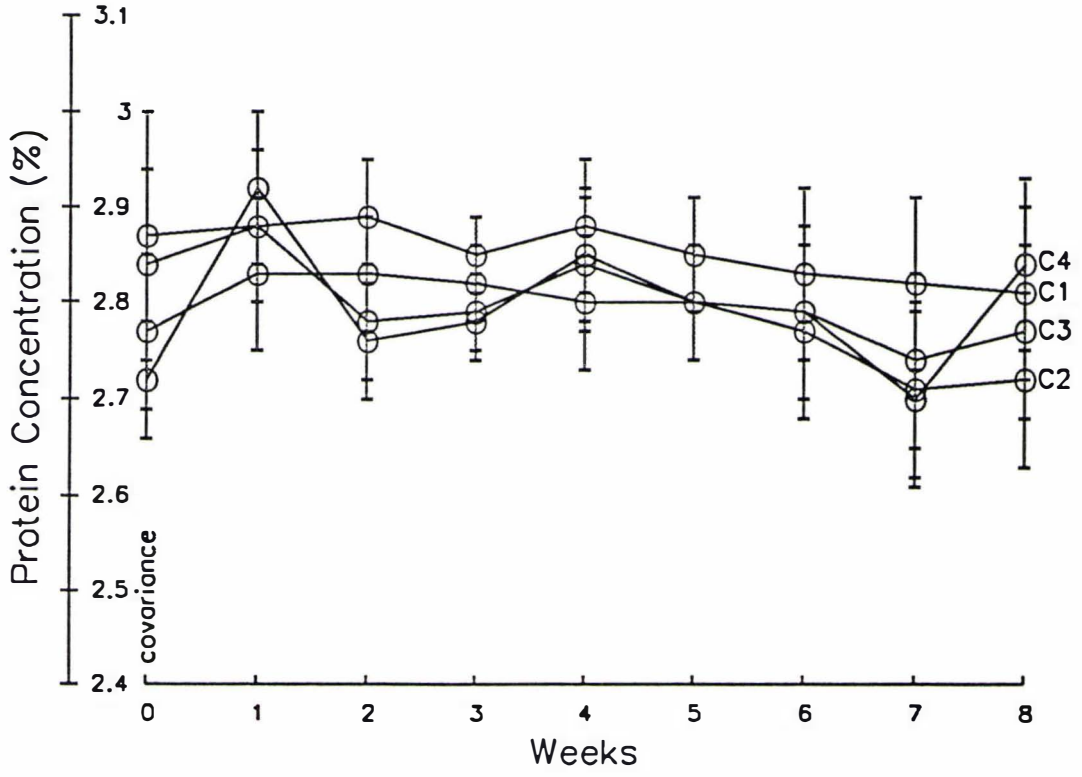

Figure 5.5 The effect of concentrates which differed in degradabilities of their proteins on milk protein concentration over the experimental period. Vertical bars indicate standard error of least square means. Abbreviations as in Figure 5.1.

The mean values of initial and final liveweight, and liveweight change are also given in Table 5.5.4. The cows on Concentrate 2 gained weight while the others lost liveweight by the end of the experiment ($p<0.05$).

The calculated net energy in milk plus liveweight change was higher in the cows on Concentrate 2 than in the cows on Concentrates 3 and 4 ($p<0.001$).

5.5.4 OVERALL RELATIONSHIPS BETWEEN NUTRITION AND PERFORMANCE

The estimated intakes of RDP and UDP are provided in Table 5.5.5 together with the RDP/ME ratios. The inclusion of urea at 1% (Concentrate 2) increased the RDP supply to the cows (from 761 to 925 g/cow daily) but the 2% inclusion resulted in no further increase in RDP intake (921 and 925 g/cow daily for Concentrates 2 and 3 respectively) mainly because the intake of silage was reduced with Concentrate 3. The Concentrate 4 (no urea) resulted in a minor increase only in RDP compared with Concentrate 1. On the other hand, UDP intakes in decreasing order were Concentrates 2, 1, 4 and 3.

The estimated intake of ME, the requirement for maintenance, net energy in milk and in liveweight, and ratio of net energy in milk plus liveweight and ME intake minus ME for maintenance are given in Table 5.5.6. The Concentrate 2 supplement resulted in the highest ME intake, ME available above maintenance, net energy retention and the highest 'apparent efficiency' of retention of energy (milk plus liveweight gain), relative to ME available above maintenance. All treatments apparently had a considerable amount of ME available above maintenance but the cows consuming Concentrate 4 had much lower values for calculated energy retention, than could have been predicted from conventional requirements.

Table 5.5.4 **Mean values for milk production and composition, and liveweight change (adjusted means).**

Mean values for:	Concentrates 1	2	3	4	SEM	Sig.
Milk yield (kg/cow daily)	8.7^{b}	10.3^{a}	8.6^{b}	8.0^{c}	0.28	**
Fat yield (g/cow daily)	310	333	313	290	45	NS
Protein yield (g/cow daily)	242^{b}	284^{a}	237^{b}	221^{b}	28	***
Fat conc.(%)	3.59^{a}	3.26^{b}	3.66^{a}	3.62^{a}	0.29	*
Protein conc. (%)	2.84	2.77	2.79	2.79	0.16	NS
Initial wt. (kg)	389	381	372	388	-	NS
Final wt. (kg)	387	387	363	372	15	NS
LWC (g/day)	-44^{ab}	129^{a}	-189^{bc}	-336^{c}	143	*
Energy retention (MJ, Milk plus live weight energy)	29^{b}	38^{a}	26^{bc}	21^{c}	3.0	***

Table 5.5.5 **The supply of rumen degradable protein (RDP, g/cow daily), undegradable protein (UDP, g/cow/daily) and the ratio of RDP/total metabolisable energy intake (g/MJ) in the total ration consumed.**

Details	Concentrates				SEM	Sig.
	1	2	3	4		
RDP supply[1/]						
As silage	276^{ab}	284^{a}	263^{b}	264^{b}	6.5	**
As concentrate	485	641	658	544	-	-
Total	761^{c}	925^{a}	921^{a}	809^{b}	6.5	***
UDP supply[1/]						
As silage	184^{ab}	189^{a}	175^{b}	176^{b}	4.3	**
As concentrate	366	376	310	334	-	-
Total	550^{b}	565^{a}	485^{d}	510^{c}	4.3	***
Total ME intake (MJ/day)	114^{b}	119^{a}	112^{b}	114^{b}	1.7	**
RDP/ME (g/MJ)	6.7^{d}	7.8^{b}	8.2^{a}	7.1^{c}	0.05	***

1/ - protein degradability of concentrates from Table 5.5.1 and of silage from Table 5.5.2

Table 5.5.6 Estimates of the partitioning of metabolisable energy intake and utilisation (MJ/cow daily) by treatment groups.

Details	Concentrates 1	2	3	4	SEM	Sig.
(1) Total ME intake (MJ/day)	114^{b}	119^{a}	112^{b}	114^{b}	1.7	**
(2) ME requirement for maintenance[1/]	53	52	51	52	1.4	NS
(3) MEI - ME_m[2/]	61	67	61	62	3.0	NS
(4) Net energy in milk[3/]	30^{b}	35^{a}	30^{b}	28^{c}	0.9	***
(5) Net energy in liveweight[4/]	-1^{ab}	3^{a}	-4^{bc}	-7^{c}	3.0	*
(6) Net energy retention[5/]	29^{b}	38^{a}	26^{bc}	21^{c}	3.0	***
(7) Efficiency[6/]	0.48^{ab}	0.57^{a}	0.43^{bc}	0.34^{c}	0.05	***

1/ $ME_m = 0.60LW^{0.75}$

2/ (1) - (2).

3/ From Equation 4 of Tyrrell and Reid (1965).

4/ 21.5 MJ/kg gain (ARC, 1980).

5/ (4) + (5).

6/ (6) / (3).

The calculated requirements for, and supply of, RDP and UDP are shown in Table 5.5.7. The cows on Concentrate 1 had a deficit in RDP supply while the others met or were in excess of the RDP requirements. The UDP supply in all treatment groups met the requirements.

Table 5.5.7 The supply of rumen degradable protein (RDP, g/cow daily), undegradable protein (UDP, g/cow daily) to the tissues of the dairy cows (Calculation based on ARC, 1980 and 1984).

Details	Concentrates			
	1	2	3	4
RDP requirement[1/]	889	928	874	889
RDP supply	761	925	921	809
Deficit/Surplus	-128	-3	+47	-80
Tissue protein[2/] supplied by microbial protein	376	393	370	376
Total tissue protein requirement	320	392	301	266
Equivalent to UDP required[3/]	457	560	430	380
UDP supply	550	566	485	510
Deficit/Surplus	+93	+6	+55	+130

1/ = 7.8ME (ARC, 1980 and 1984).

2/ = 3.3ME (ARC, 1980 and 1984).

3/ = Total tissue protein requirement / 0.70 (ARC, 1980,1984).

The regression equations that best described the relationships between performance and the intakes of MEI, RDP and UDP are shown in Table 5.5.8. These equations suggested that the cows performance was affected by the intakes of MEI, RDP and UDP. Thus the high performance of the cows on Concentrate 2 was associated with high intakes of MEI, RDP and UDP. The cows on Concentrate 1 ate less RDP, the cows on Concentrate 3 ate less UDP and the cows on Concentrate 4 ate less RDP and UDP compared with the cows on Concentrate 2. The cows on Concentrate 4 produced less milk than the others because they consumed less RDP and UDP than the other groups despite the similar intake of ME.

The correlation analyses were also examined between the intakes of nutrient components (ME, RDP, UDP and CPl) and animal performance including energy terms. The results are shown in Table 5.5.9.

5.5.5 SUMMARY OF THE RESULTS

1. Silage DM intake was increased by Concentrate 2 supplementation compared to other concentrates. This is likely to be due to extra UDP from concentrate.

2. Yields of milk and milk protein were increased by Concentrate 2 compared with other concentrates.

3. Cows on Concentrate 2 gained more weight than cows on other concentrates.

4. Increases in yields and liveweight were due mainly to increases in intakes of ME and UDP by cows on Concentrate 2.

Table 5.5.8 **Significant regression equations describing the influences of the intakes of metabolisable energy (MEI, MJ/cow daily), rumen degradable protein (RDP, g/cow daily) and undegradable protein (UDP, g/cow daily) on milk yield (kg/cow daily), net energy in milk (MJ/cow daily) and net energy in milk plus liveweight (MJ/cow daily).**

Regression equations						r^2
Milk Yield	=	-14.6 + 0.06MEI	+ 0.01RDP	+ 0.02UDP		0.93
		(1.3) (0.02)	(0.001)	(0.002)		
		**	***	***		
	=	-15.7 + 0.12MEI	+ 0.01CPI			0.87
		(1.8) (0.02)	(0.001)			
		***	***			
	=	-11.8 + 0.01RDP	+ 0.02UDP			0.91
		(1.1) (0.001)	(0.001)			
		***	***			
	=	-14.0 + 0.20MEI				0.63
		(2.9) (0.03)				
		***				
Net Energy in Milk	=	-36.0 + 0.18MEI	+ 0.02RDP	+ 0.05UDP		0.82
		(6.2) (0.08)	(0.003)	(0.01)		
		*	***	***		
	=	-38.5 + 0.32MEI	+ 0.02CPI			0.79
		(6.7) (0.07)	(0.004)			
		***	***			
	=	-27.3 + 0.03RDP	+ 0.07UDP			0.80
		(4.9) (0.003)	(0.01)			
		***	***			
	=	-33.3 + 0.56MEI				0.55
		(9.7) (0.08)				
		***				
Net Energy Retention	=	-92.2 + 0.05RDP	+ 0.16UDP			0.46
		(21.6) (0.01)	(0.03)			
		**	***			
	=	-89.4 + 1.03MEI				0.25
		(33.6) (0.29)				
		**				
Silage DM Intake	=	2.7 + 0.01UDP				0.54
		(0.9) (0.002)				
		** ***				
	=	5.26 + 0.01CUDP				0.90
		(0.8) (0.002)				
		* *				

MEI = Total Metabolisable energy intake(MJ/cow daily).
RDP = Total Rumen degradable protein intake (g/cow daily).
UDP = Total Undegradable protein intake (g/cow daily).
CUDP = Concentrate UDP intake (g/cow daily)

Table 5.5.9 Correlation coefficients between performance and nutrition (the lower figures are probability > |R| under Ho: Rho=0 / n=36).**

	MY	ER	ME	LWE	MEI	RDP	UDP	CPI
MY	1.000 0.000							
ER	0.668 0.0001	1.000 0.000						
ME	0.963 0.0001	0.618 0.0001	1.000 0.000					
LWE	- -	0.896 0.0001	- -	1.000 0.000				
MEI	0.790 0.0001	0.504 0.002	0.736 0.0001	0.220 0.196	1.000 0.000			
RDP	0.565 0.0003	0.328 0.051	0.572 0.0003	0.161 0.349	0.271 0.110	1.000 0.000		
UDP	0.708 0.0001	0.578 0.0002	0.636 0.0001	0.410 0.013	0.676* 0.0001	-0.106 0.540	1.000 0.000	
CPI	0.843 0.0001	0.562 0.0004	0.817 0.0001	0.330 0.049	0.902* 0.0001	0.334 0.046	0.973 0.0001	1.000 0.000

* These parameters are not independent to each other.

** The probability that a R statistic would obtain a greater absolute value than that observed given that the true parameter is 0.

5.6 DISCUSSION

5.6.1 EFFECT OF CONCENTRATE SUPPLEMENTATION ON FEED INTAKE

One of the objectives of the present study was to investigate the effect of concentrates which differed in the degradability of their protein, on silage intake of dairy cows. The intakes of DM, ME and the production of the cows in the present study were lower than the previous experiment on fresh forage (Chapter 4). Also, the present silage was lower in ME concentration per kgDM than the fresh forage. The generally lower voluntary intake of DM from silage than from fresh forage has been reported previously (Moore *et al.*, 1960; Demarquilly, 1973).

Intakes of silage DM by cows fed on Concentrates 1, 3 and 4 were similar whereas the cows on Concentrate 2 consumed more silage DM than the cows on Concentrates 3 and 4. The results suggested that the supply of crude protein and its components (RDP and UDP), or the concentrations of protein in the concentrates in the rations may affect the silage DM intake.

When considering the supply of crude protein, RDP and UDP, the cows on Concentrate 2 ate more silage DM than the cows on Concentrate 3 and 4. This was probably related to higher intakes of UDP and CP by cows on Concentrate 2 and is in agreement with many research reports which have recorded improved intakes of silage when it is supplemented with concentrate with increased levels of crude protein or with protein that is resistant to degradation in the rumen (Castle and Watson, 1976; Gordon, 1979; Mo, 1980; Rae *et al.*, 1986). The cows on Concentrate 2 and 3 had similar crude protein concentration in the total ration (11.6 and 11.5% respectively) and had similar RDP intakes (925 and 921 g/cow daily respectively) but the cows on Concentrate 2 consumed more silage than the cows on Concentrate 3 probably due to higher UDP intakes (565 and 485 g/cow daily respectively).

To separate which protein components had contributed to the effect of increased silage DM intake, the relationships between silage DM intake (kg/cow daily) and protein components (RDP and UDP) from concentrate or from total intake were determined (Figure 5.6). A significant positive relationship between silage DM intake and undegradable protein (UDP) intake both from concentrate and from total intake was evident but there was no close relation between silage DM intake and rumen degradable protein (RDP) both from concentrate and from total intake. It can be concluded in the present study that intakes of UDP from concentrate had a major effect on increased silage DM intake and consequently increased total UDP intake.

Castle and Watson (1976) supplemented silage with either barley, groundnut cake or mixture of barley and groundnut cake to lactating cows, and reported increases in silage intake when groundnut cake was supplemented but decreases in silage intake when barley or the mixture of groundnut cake and barley were supplemented. Similar result was obtained by Rae *et al.* (1986) when lactating cows were supplemented with cereal concentrate or fishmeal and soyabean meal mixtures.

The effect of the level of protein in the concentrate for cows given silage diets has been much discussed as a result of the possible limitations in the supply of protein from ensiled diets. In many of the trials, increasing the proportion of protein in the concentrate resulted in an increase in digestibility and in silage intake (Reeve *et al.*, 1989). Reeve *et al.* (1989), for instance, supplemented late cut silage (63.2-63.3% DOMD) with 6 kg/day of either 36% or 18% crude protein compound feeds and reported that silage intakes were improved by 0.09 kgDM/day by feeding the high CP compound.

In the present study, the silage DM intake by cows on Concentrate 2 was higher than cows on Concentrate 4. This was probably associated with the higher concentration of protein in the Concentrate 2 relative to the Concentrate 4 (22.6 and 19.5% CP respectively).

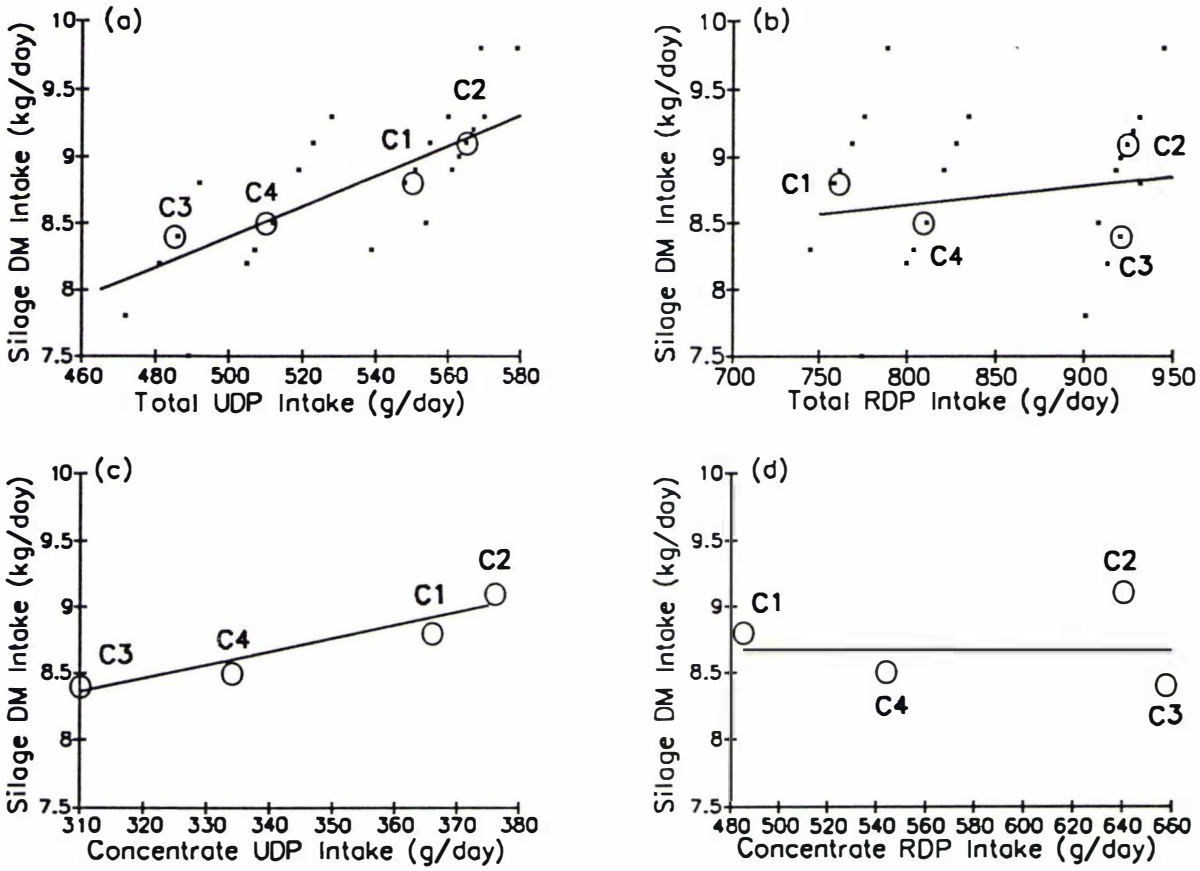

Figure 5.6 Relationships between silage DM intake and intakes of total UDP, total RDP, concentrate UDP and concentrate RDP.
Data for individual cows shown (.).
Mean values for each treatment shown (o).

(a)	y =	0.01x +	2.7	r^2 = 0.54
		(0.002)	(0.9)	
		***	**	
(b)	y =	0.001x +	7.5	r^2 = 0.04
		(0.001)	(1.02)	
		NS	***	
(c)	y =	0.01x +	5.26	r^2 = 0.90
		(0.002)	(0.8)	
		*	*	
(d)	y =	0.00006x -	8.7	r^2 = 0.0003
		(0.003)	(1.6)	
		NS	*	

5.6.2 EFFECT OF CONCENTRATE SUPPLEMENTATION ON ANIMAL PERFORMANCE

Milk yield in all treatments declined from the initial yield (from approximately 12.2 to 8.0-10.3 kg/cow daily) before the start of the experiment and was slightly lower than in the previous experiment (ranged from 9.2 to 11.7, Chapter 4) when cows were fed on fresh forages. This can be attributed to the reduced level of concentrate feeding during the experimental period (4.5 kgDM concentrate/cow daily compared to 6 kgDM concentrate/cow daily in the pre-experimental period) and to the much lower quality of the basal diet (silage) in the present study compared with that (pasture) in the previous study (Chapter 4).

In the present study, the cows receiving Concentrate 2 produced higher yields of milk and milk protein than the other groups. This was probably due to the fact that the cows on Concentrate 2 had higher values of ME and CP intakes relative to other groups. The higher ME and CP intakes partly reflected the higher silage DM intake compared to the other groups.

Many research reports have shown increases in yield of milk and milk protein when the concentration of protein in the supplement increased (Gordon, 1979; Gordon *et al.*, 1981; Oldham *et al.*, 1985; Small and Gordon, 1985) although others did not find this relationship (Gordon, 1980; Gordon and Unsworth, 1986). Experimental work by Reeve *et al.* (1989) showed an increase in milk protein yield when the concentration of protein in the concentrate was increased from 18 to 36% CP. Gordon and Peoples (1986) also reported an increase in the yield of milk protein when protein concentration of the supplement was increased from 16 to 21% CP. More recently, Davies (1992) reported improved yields of milk and milk protein when concentration of protein in the supplement increased from 21 to 35% CP. In all of these trials, increases in milk yield were associated with increases in silage DM intake.

It appears that increasing the proportion of protein in the concentrate increases yields of milk and milk protein in the majority of cases. The extent of the response is dependent upon the degree of the associated effects on digestibility and intake of silage (Thomas and Thomas, 1989). The marked responses in milk output were associated

with above average increases in silage intake, and the additional ME supply from these increases accounted for a major proportion of the increase in milk yield. However, the differences in crude protein concentration in the concentrates in the present study were small.

It is also important to remember that the quality of silage used in the present experiment was very low and in marked contrast to the normal high quality silage used in the reported European studies - and hence may well have influenced response and reaction levels.

In the present study, improved yields of milk and milk protein were also probably due to increases in amino acid supply to the small intestine by use of low protein degradability feedstuffs in the concentrate.

Small and Gordon (1985) supplemented silage with 18% CP of either soyabean meal or fishmeal to dairy cows and found that animal production was unaffected by protein sources (degradability of protein). However, fishmeal improved milk protein concentration.

5.6.3 OVERALL RELATIONSHIPS BETWEEN NUTRITION AND PERFORMANCE

In Table 5.5.5, it was assumed that 0.60 of the crude protein intake from the silage was degraded. Webster *et al.* (1982) assumed that forages contain a certain amount of undegradable protein and that the rest is degradable. They used data presented by Wilson and Strachan (1980) to describe a simple equation relating protein degradability of silage to concentration of crude protein (%CP) by assuming a certain amount of undegradable protein (of 22.5 g/kgDM) and obtained:

$$dg = 100(\%CP - 22.5)/\%CP$$

The present study adopted this equation to estimate protein degradability of silage and is shown in Table 5.5.5.

The supply of RDP per unit of ME intake (Table 5.5.5), in Concentrates 1 and 4 had lower ratios of RDP/ME (6.7 and 7.1 respectively) than the value suggested by ARC (1984; 8.1 gRDP/MJME). Low ratios would be expected to result in low rates of microbial protein synthesis (ARC,1984). In the present study, the cows on Concentrates 2 and 3 had a calculated ratio of RDP/ME of 7.8 and 8.2 g/MJ respectively which is close to the ARC value, but the Concentrate 2 group showed the highest net energy retention (35 MJ; Table 5.5.6). This was probably due to a higher UDP intake in cows on Concentrate 2 than those on Concentrate 3.

The cows on Concentrate 2 had higher intakes of ME, RDP and UDP than the others, which resulted in higher yields, net energy retention and higher 'apparent' efficiency of ME utilisation above maintenance relative to the other groups. Therefore, when animals were fed on tropical grass silage of low quality, the supplies of energy, crude protein and its components (RDP and UDP) were a major determinant in performance. As can be seen by the multiple regressions (Table 5.5.8), the performance was related to total intakes of ME, crude protein, RDP and UDP. However, the interpretation of this relationship should be taken with caution, since these parameters seem to be auto-correlated.

From Table 5.5.6, the 'apparent' efficiency of utilisation of ME above maintenance for cows on the Concentrate 2 was a reasonable value (close to 0.6; ARC, 1984), while for cows on other rations it was very low. Possible reasons were discussed previously in the experiment with cows fed fresh forages (Section 4.2.6.3; Chapter 4). The possible reasons included an overestimate of M/D values of the feeds, an underestimate of maintenance requirements rather than exact measures, errors in weighing animals precisely, no allowance being made for reduction in roughage digestibility due to concentrate feeding, and effect of reduced level of feeding.

When intakes of individual components (ME, RDP, UDP or CP) of total ration were separately plotted against milk yield, net energy in milk or net energy retention (Figures 5.7, 5.8 and 5.9), the significant relations between milk yield and intakes of ME or CP were evident. There were also close significant relations between net energy in milk and intakes of ME or CP. Intakes of ME, UDP and CP were closely related to net energy retention. Care must be taken when interpretation of these relationships is made. The estimated total intakes of ME, RDP, UDP and CP obtained from the

products of silage DM intake and concentrations of such nutrient components plus the products of concentrate DM intake and concentrations of nutrient components from the particular concentrates. In the case of silage, it is obvious that the nutrient components are auto-correlated. However, in the case of concentrate, the nutrient components vary considerably.

In the present study, the concentrates were fed twice daily which may be too infrequent to maintain the ammonia concentration in the rumen at the required level. Some 5-6 hours after feeding the concentration of ammonia may drop below the required level (eg. 150 mgNH_3-N/litre as suggested by the results reported in Chapter 7). Increases in frequency of feeding is one possible alternative but this needs intensive labour, and is probably impractical and uneconomic. Another possible alternative is to supply fermentable protein and by-pass protein by the combination of a "block" with urea, molasses and by-pass protein. The expected increase in digestibility of silage and intake of silage, and consequently in nutrient supply to the cows, would probably enhance milk production and animal performance.

5.6.4 AN ECONOMIC ASSESSMENT OF MARGINAL FINANCIAL RETURNS

An economic assessment was made of the marginal returns from the milk produced per treatment less the cost of the concentrates (Table 5.6.1). It showed that the marginal return was highest when feeding silage plus Concentrate 2. The marginal returns from the Concentrates 1 and 3 were similar while from the Concentrate 4 was lowest. With the present price of milk and the cost of concentrate, farmers will achieve greater profit by feeding silage as their main source of feed for dairy cows during the dry season and supplementing moderate level i.e. 5 kgDM of concentrate containing 1% urea and low degradable protein sources (cotton seed meal, palm meal and maize) to give approximately 0.60 protein degradability in the concentrate as in the Concentrate 2 in the present experiment.

Table 5.6.1 An economic assessment of marginal financial returns.

Details	Concentrates			
	1	2	3	4
Milk yield (kg/cow daily)	8.7	10.3	8.6	8.0
Milk return (NZ$)	4.79	5.67	4.73	4.40
Cost of concentrate (NZ$)	1.31	1.32	1.32	1.52
Marginal Surplus (NZ$)	3.46	4.35	3.41	2.88

1/ NZ$ 0.55/kg milk.

2/ NZ$ 0.29 for Concentrates 1, 2 and 3; NZ$ 0.34 for Concentrate 4.

5.7 CONCLUSIONS

1. Concentrate 2 (1% urea) increased silage intake compared to Concentrates 3 and 4. The Concentrate 2 ration resulted in higher milk yield ($p<0.01$), protein yield ($p<0.001$) and liveweight change ($p<0.05$) while fat concentration was lower relative to other rations.

2. With tropical forages, the importance of RDP and UDP intakes was evident as shown by multiple regression analyses. In the present study, the intake of ME among the treatment groups was not very different. Milk yield and net energy in milk was related to MEI plus alternative aspects of protein intake (RDP and UDP). Net energy retention (milk plus liveweight) was however only related to RDP and UDP intakes. The Concentrate 2 cows had higher RDP, UDP and ME intakes which resulted in higher milk yield, net energy retention and efficiency of ME used above maintenance relative to other groups.

3. As the Concentrate 2 (1% urea) showed a better response over the others (0 or 2% urea), the optimum level of urea in the concentrate was shown to be 1%. However, this can only be applied to the situation where moderate level of concentrate (4.5 kgDM) was supplemented to poor quality silage as in the present study. Further research is needed to investigate the optimum level of urea added to concentrate i.e. 0.5, 1.0 and 1.5% when better quality forages are fed.

4. From a practical point of view, and with inadequate information to confirm the appropriate level of urea in the concentrate at present, 1% urea should probably be added to the concentrate to supply an adequate level of RDP and thus to maintain an adequate level of ammonia in the rumen (usually above 150 mgNH_3-N/litre of rumen fluid). In the tropics where the typical forages are low in protein, not only intake of ME but also intakes of RDP and UDP should be taken into account when the ration is formulated.

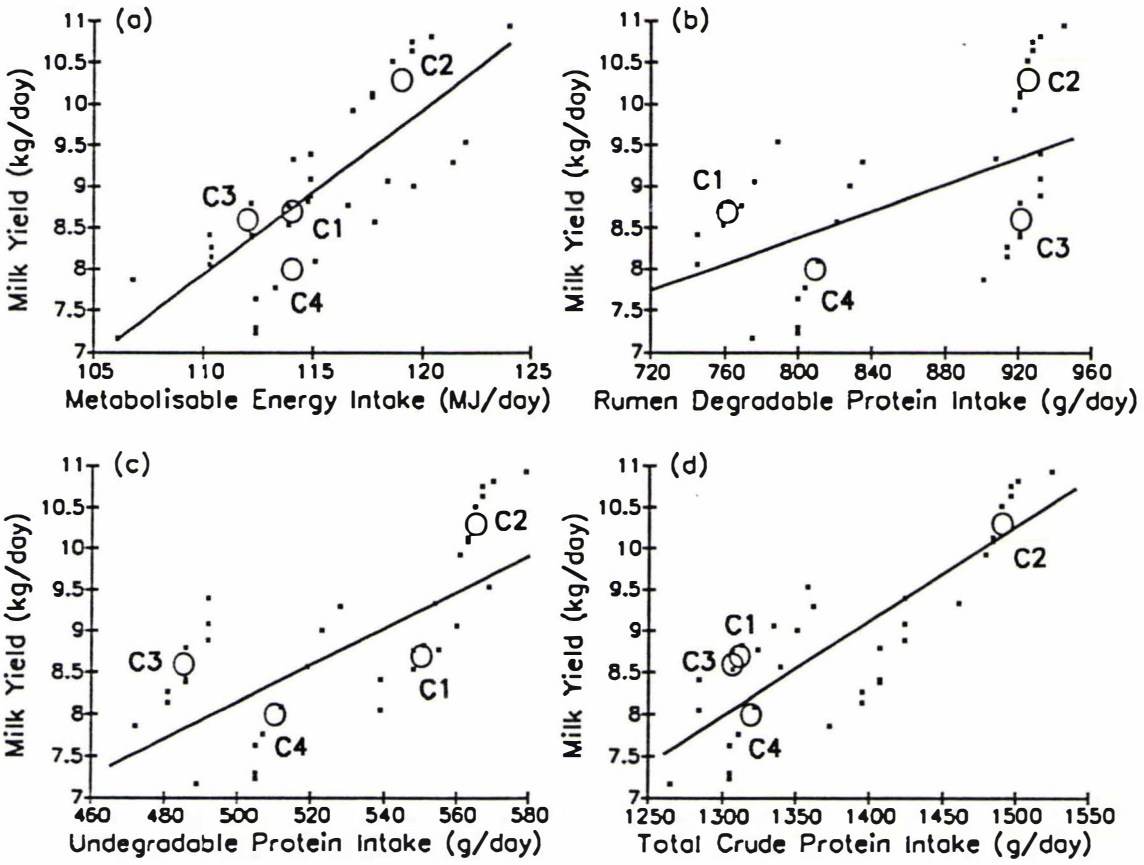

Figure 5.7 Relationships between milk yield and intakes of ME, RDP, UDP and CP.

Data for individual cows shown (.).

Mean values for each treatment shown (o).

(a)	$y = 0.199x - 13.96$		$r^2 = 0.64$
	(0.026)	(2.94)	
	***	***	
(b)	$y = 0.008x + 1.97$		$r^2 = 0.33$
	(0.002)	(1.72)	
	***	NS	
(c)	$y = 0.022x - 2.85$		$r^2 = 0.50$
	(0.004)	(2.01)	
	***	NS	
(d)	$y = 0.011x - 6.84$		$r^2 = 0.71$
	(0.001)	(1.71)	
	***	***	

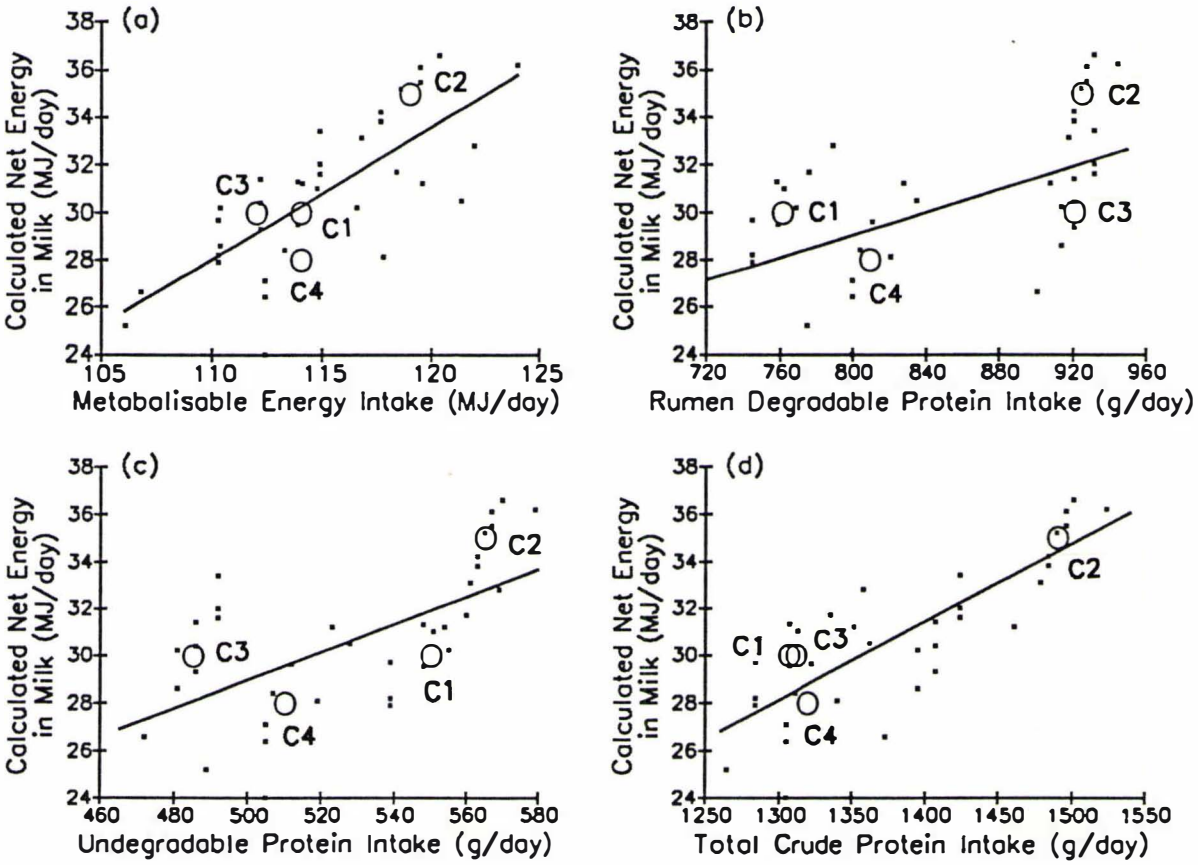

Figure 5.8 Relationships between calculated net energy in milk and intakes of ME, RDP, UDP and CP.
Data for individual cows shown (.).
Mean values for each treatment shown (o).

(a)	y =	0.557x -	33.26	r^2 = 0.56
		(0.084)	(9.69)	
		***	**	
(b)	y =	0.024x +	9.85	r^2 = 0.33
		(0.006)	(5.11)	
		***	NS	
(c)	y =	0.059x -	0.55	r^2 = 0.40
		(0.012)	(6.59)	
		***	NS	
(d)	y =	0.033x -	14.76	r^2 = 0.67
		(0.004)	(5.51)	
		***	*	

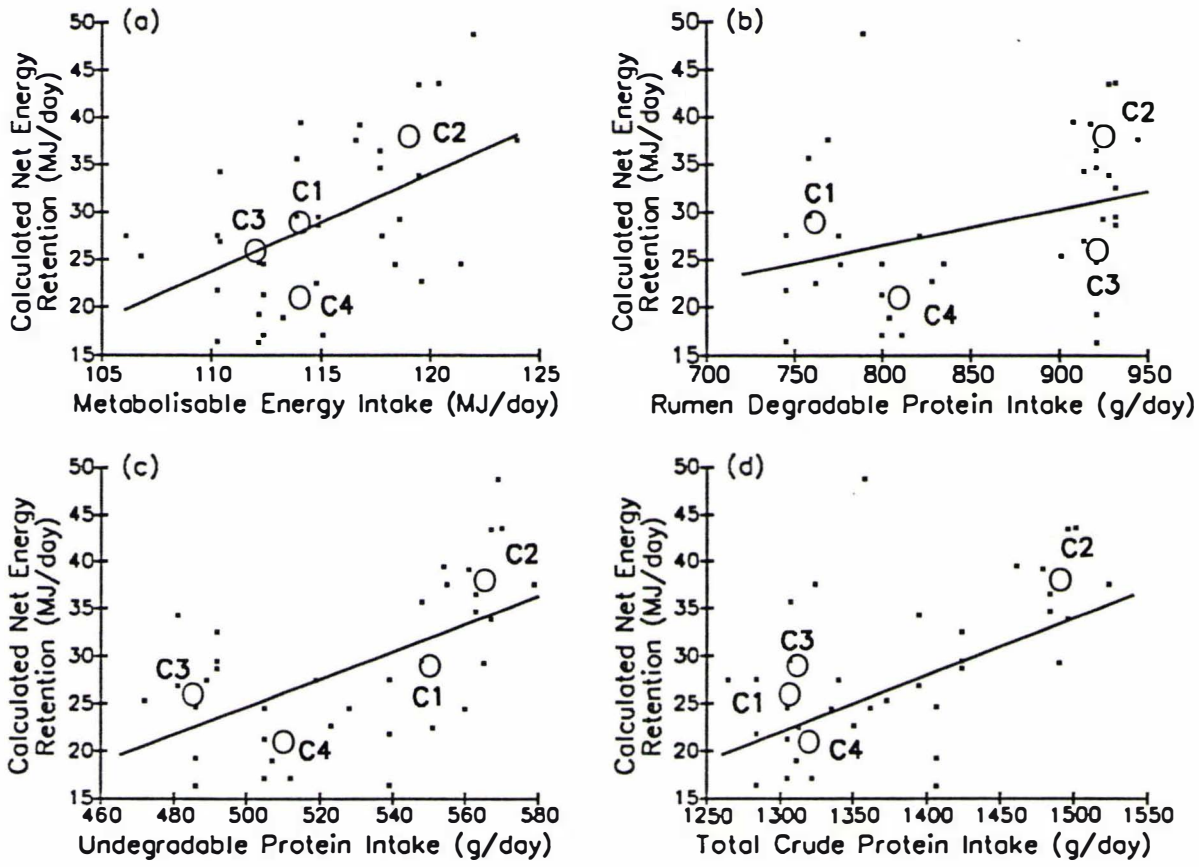

Figure 5.9 Relationships between calculated total energy retention (milk plus liveweight) and intakes of ME, RDP, UDP and CP.
Data for individual cows shown (.).
Mean values for each treatment shown (o).

(a)	y =	1.029x -	89.44	r^2 = 0.27
		(0.293)	(33.65)	
		**	*	
(b)	y =	0.038x -	4.00	r^2 = 0.11
		(0.018)	(15.79)	
		*	NS	
(c)	y =	0.145x -	47.93	r^2 = 0.33
		(0.035)	(18.64)	
		***	*	
(d)	y =	0.06x -	56.07	r^2 = 0.32
		(0.015)	(21.11)	
		***	*	

CHAPTER 6

AN ESTIMATION OF DRY MATTER AND PROTEIN DEGRADABILITY IN FEEDSTUFFS COMMONLY FED TO DAIRY COWS IN THAILAND

6.1 INTRODUCTION AND OBJECTIVES

There is a wide variety of feedstuffs used in the concentrates which are fed to dairy cattle in Thailand. These feedstuffs vary in their nutritive values, and in the extent of dry matter and protein degradability. The degradability of feed protein has recently been recognised as a major factor involved in the metabolism of protein and non-protein nitrogen (NPN) in ruminants. The estimated degradability of feed proteins can give some indication of the probable *in vivo* utilisation of the protein.

The extent to which a protein source is degraded in the rumen has a marked influence on the fate of the ingested nitrogen. The degradable fraction is converted largely to ammonia, fatty acids and carbon dioxide, with a portion of the ammonia being used for microbial protein synthesis in the rumen and the remainder being lost as urea. The undegradable fraction escapes digestion in the rumen and subsequently becomes available for intestinal digestion and absorption (ARC, 1980, 1984).

Many of the values for protein degradability which are currently available have been estimated indirectly from *in vitro* solubility data (ARC, 1980). On the other hand, some of the values measured *in vivo* are crude estimates and vary widely even for the same feed protein (Chalupa, 1975). As reported by Miller (1982), *in vivo* measurements of feed protein degradability within the rumen generally use animals equipped with double re-entrant cannulae in the rumen and abomasum or terminal ileum. This technique is often used as the reference method for estimating feed protein degradability but has limited usefulness for large-scale determinations of degradability in practice.

Unfortunately the majority of *in vivo* degradability values have been obtained from sheep, and therefore, it may be inappropriate to apply these values to dairy cattle. The paucity of accurate estimates of degradability, and the variability generally observed in these studies, is due to the difficult nature of the experimental procedures involved with the *in vivo* methods which include complex surgical preparations of experimental animals, complicated methods for measuring microbial protein, and extensive sample analysis. In addition, the *in vivo* methods are also more expensive than *in vitro* and *in sacco* methods.

Of the various other methods suggested as alternatives to the *in vivo* technique, only a few have been generally accepted. One of the more promising approaches widely accepted is the nylon bag technique, which Mehrez and Orskov (1977) considered as suitable for determining degradation of protein. The most simple application of the technique for estimating protein degradation is to suspend the bag in the rumen for an arbitrary period of time, thus giving a relative estimate of protein degradation. Many reviews covering various aspects of this method have been published and extensively discussed (Orskov and McDonald, 1979; Mathers and Miller, 1981; McDonald, 1981; Broderick, 1982; Miller, 1982; Stern and Satter, 1982; Lindberg, 1985).

Because information for feed protein degradation in Thailand is very limited, the dry matter and protein degradability of 10 feedstuffs which are widely used in concentrate supplements were therefore determined by the nylon bag technique at Khon Kaen University, Khon Kaen, Thailand.

6.2 MATERIALS AND METHODS

6.2.1 ANIMALS AND THEIR FEEDING

Two dairy heifers (Friesian crossbred with local dairy cattle), equipped with cannulae in the rumen were used. They were fed, at the maintenance level, 4 kgDM of urea-treated rice straw with an additional 2 kg of balanced concentrates, given as two equal meals per day, at 0800 and 1600 h.

6.2.2 FEEDSTUFFS

Ten selected feedstuffs; tapioca, soyabean meal, solvent extracted cotton seed meal, hydraulic extracted cotton seed meal, groundnut meal, sesame meal, ground maize, palm meal, corn meal and rice bran were used in the present determination. A brief description of individual feedstuffs is given as follows:

By-product from oil seed

1. **Cotton seed meal** (hydraulic extract): This is the by-product from the production of oil. The oil is extracted by an hydraulic process. The residue is then dried and used for animal feed.

2. **Cotton seed meal** (solvent extract): The oil from whole cotton seed is extracted by partial mechanical extraction and then by solvent extraction process. The residue is dried and used for animal feed.

3. **Groundnut meal**: It is a by-product of the peanut industry; so-called ground peanut cake is the product which remains after the extraction of the oil of peanuts by pressure and solvents.
4. **Sesame meal**: The oil meal is produced from the entire seed by a solvent extraction process. The residue is used for animal feed.

5. **Soybean meal**: Soybean meal is the ground residue remaining after the removal of most of the oil from soybeans by solvent extraction.

6. **Palm meal**: It is also a by-product of the oil industry. The residue left after solvent extraction is used for stockfeed.

Starch, grain and its by-products

7. **Tapioca**: Tapioca is a major crop for stockfeed in Thailand. The underground root is harvested, chopped and sun-dried to become tapioca chips.

8. **Maize**: It is also a major crop for animal feed which has been ground before feeding.

9. **Corn meal**: Corn meal is a by-product of starch and oil industry.

10. **Rice bran**: A by-product from rice grain and widely use as animal feed.

6.2.3 DEGRADATION IN THE RUMEN

The feedstuffs taken from DPO's feedmill, which produces and distributes concentrates to the majority of the dairy farmers in Thailand, were ground through a 3 mm screen and the rumen degradation values obtained by weighing approximately 5 gDM of individual feedstuff into each of the nylon bags (outer dimensions 80 x 110 mm; pore size 47 µm, Estal Mono, Switzerland). A total of 60 bags were suspended in the rumen of each heifer (10 feedstuffs and 6 times of removal from the rumen) prior to the morning feeding. A bag for each feed per animal was incubated in the rumen for 2, 4, 6, 12, 24 and 48 hours, and then removed and washed with running cold tap water until clear (approximately 5-6 minutes), and then dried at 60°C for 24 h (Lindberg, 1982). After weighing each bag individually, two bags (one from each animal) of each feed at each incubation period were pooled to make one representative sample large enough for N determination. To characterise the degradation of feed samples in the rumen, the degradation values were then fitted to the equation of Orskov and McDonald (1979):

$$dg = a + b(1-exp^{-ct}).$$

where:

- dg = the degradation at time t.
- a = the constant for the instantly degradable fraction of the feed.
- b = the constant for the slowly degradable fraction of the feed.
- c = the rate of degradation of 'b'.

The constants were computed by a curve fitting programme and the potential degradability determined as a product of $a + b$.

The effective degradabilities of protein were estimated by the following equation (Orskov and McDonald, 1979):

$$dg = a + bc/c+k.$$

where dg is the effective degradability; a, b and c are the constants as mentioned previously; and k is rumen fractional outflow rate of undegraded protein which, in the present study, was assumed to be 0.046/h (Orskov and McDonald, 1979).

This effective degradability *(a + bc/(c + k))* is assumed to be converted to microbial protein at an efficiency of 1.0 (ARC, 1980). However, the new metabolisable protein system proposed by IDPW (1991) described the term '*a*' as "quickly degraded N which is assumed to be converted to microbial protein at an efficiency of 0.8" and the term '*bc/c+k*' as "slowly degraded N which is assumed to convert to microbial protein at an efficiency of 1.0" (IDPW, 1991; Webster, 1992).

6.2.4 CHEMICAL ANALYSIS

The feed samples and their rumen-undegraded residues were analysed for DM (60°C, 24 h) and N concentration (Kjeldahl).

6.3 RESULTS

6.3.1 CHEMICAL ANALYSES OF THE FEEDS

The dry matter and crude protein percentage of individual feedstuffs used in the present determinations are presented in Table 6.3.1.

Table 6.3.1 The percentage of dry matter and crude protein of feedstuffs.

Feedstuffs	Dry matter (%)	Crude protein (% DM)
Cotton seed meal (hydraulic extract)	89.8	41.0
Cotton seed meal (solvent extract)	89.8	45.1
Groundnut meal	91.2	47.2
Sesame meal	92.1	42.4
Soybean meal	90.0	49.1
Palm meal	94.1	21.0
Tapioca	87.7	2.0
Maize	88.8	9.9
Corn meal	90.6	22.9
Rice bran	91.4	14.2

6.3.2 DRY MATTER DEGRADATION

Values for percentage dry matter disappearance from the nylon bags or degradation in the rumen at various times of incubation of individual feedstuffs are presented in Table 6.3.2. Increases in DM degradation with time were found for all feeds up to 48 h of incubation. The constant for the instantly degradable fraction (*a*) of DM was highest for maize (12.2) and lowest for palm meal (0.4%) with the other feeds being intermediate in value (range from 4.7 to 10.5%). However, the maximum potential DM degradation value (*a+b*) was highest for soyabean meal (92.9%) with rice bran (40.9%) and again palm meal (46.3%) at the lower end of the scale. The remaining feeds showed intermediate values between 60 to 80% DM degradation.

Figure 6.1 shows the curves drawn from fitted single exponential equations (r=0.87-0.96) of percentage of DM disappearance from the nylon bags, against time. From these curves, it was shown that during the first period of incubation (6-18h) the rate of DM disappearance was very rapid but it then declined to zero over the remaining period. The actual percentages of DM disappearance from nylon bags at various time of incubation of individual feeds are illustrated in Figure 6.3.

6.3.3 PROTEIN DEGRADATION

Protein degradability values for individual feedstuffs at various incubation times together with their calculated 'constant' values are presented in Table 6.3.3. The rate constant (*c*) of ruminal protein degradation was highest for corn meal and palm meal, being 1.09 and 0.81 respectively. Soyabean meal, cotton seed meal, groundnut meal and sesame meal showed low values, ranging from 0.07-0.12 (Table 6.3.3). The instantly degradable fraction (*a*) of protein was highest in sesame meal (11.9%) and lowest in cotton seed meal (-3.17%, for the hydraulic extract) with corn meal also showing a very low value of 0.06%. The potential protein degradation values (*a+b*) were in descending order from groundnut meal, showing the highest value (97.2%), then soyabean meal, sesame meal, cotton seed meal (solvent extract), cotton seed meal

(hydraulic extract), palm meal, corn meal, rice bran and finally maize with the lowest value (55.6%). The calculated effective protein degradabilities (*dg*) are also given in Table 6.3.3.

Figure 6.2 showed the curves fitted by single exponential equations (r=0.87-0.99) of individual feedstuffs. The rate of N disappearance showed a similar trend to the rate of DM disappearance, being very rapid during the first 6-18 hours and then declining over the remaining 30 to 40 hours. Of additional interest was the extremely rapid rate of N disappearance in palm meal and corn meal, and to a lesser extent in rice bran and maize. However only 50-70% of the N content in these four feeds was degraded in the rumen compared with, for example, 90-97% of that in groundnut meal and soyabean meal. The actual percentages of N disappearance from nylon bags at various time of incubation of individual feeds are illustrated in Figure 6.4.

The values determined in this Chapter were subsequently used to formulate rations for the experiment described in Chapter 5 and also used to estimate protein degradabilities of concentrates in Chapter 4.

Table 6.3.2 Dry matter disappearance (%) from the feedstuffs in nylon bags incubated in the rumen of heifers.

Hours	Tapioca	Soybean Meal	Cotton[1/] Seed Meal	Cotton[2/] Seed Meal	Groundnut Meal	Sesame Meal	Maize	Palm Meal	Corn Meal	Rice Bran
2	42.8	37.5	17.0	30.6	43.0	36.9	30.2	35.9	26.6	21.7
4	44.1	38.5	17.4	31.4	46.9	42.2	34.2	40.0	26.8	21.8
6	50.6	43.4	19.2	37.9	50.2	49.5	34.4	40.4	30.7	23.1
12	55.4	59.7	23.1	50.0	72.4	57.8	42.9	41.1	35.6	28.0
24	66.4	80.9	39.5	60.6	85.6	85.3	55.8	49.6	41.1	35.2
48	79.6	94.9	56.9	69.4	94.2	92.0	76.4	53.2	59.2	45.1
Constants										
a	4.71	10.53	7.16	6.13	7.90	9.46	12.16	0.44	8.72	6.47
b	63.26	82.37	65.09	59.12	81.78	80.25	62.25	45.82	43.81	34.46
c	0.27	0.09	0.03	0.14	0.15	0.11	0.07	0.63	0.10	0.12
a + *b*	67.97	92.90	72.25	65.25	89.68	89.71	74.41	46.26	52.53	40.93
r	0.91	0.96	0.96	0.96	0.96	0.95	0.91	0.95	0.87	0.89

1/ - hydraulic extract. 2/ - solvent extract.

Table 6.3.3 Nitrogen disappearance (%) from the feedstuffs in nylon bags incubated in the rumen of heifers.

Hours	Soybean Meal	Cotton[1/] Seed Meal	Cotton[2/] Seed Meal	Groundnut Meal	Sesame Meal	Maize	Palm Meal	Corn Meal	Rice Bran
2	23.78	6.02	23.61	33.42	40.54	38.43	60.94	63.88	40.92
4	27.76	13.76	29.65	37.21	51.19	41.34	64.22	65.63	44.05
6	47.72	21.10	31.77	41.55	51.81	42.94	66.40	68.99	44.48
12	59.00	41.50	49.62	67.38	55.14	47.40	67.27	69.03	48.87
24	76.95	65.67	65.40	85.11	85.71	54.33	78.54	70.82	61.52
48	94.94	71.35	81.68	98.44	94.38	68.14	79.88	77.70	73.05
Constants									
a	4.57	-3.17	6.56	7.24	11.92	2.43	0.30	0.06	4.68
b	87.97	80.01	74.93	89.93	77.54	53.13	72.14	70.77	57.90
c	0.09	0.07	0.07	0.09	0.12	0.37	0.81	1.09	0.28
a+b	92.54	76.84	81.49	97.17	89.46	55.56	72.44	70.83	62.58
r	0.98	0.99	0.98	0.98	0.91	0.90	0.97	0.97	0.87
dg	62.79	45.11	51.78	66.75	67.97	49.69	68.56	67.96	54.41

1/ - hydraulic extract. 2/ - solvent extract. *dg* - effective degradability.

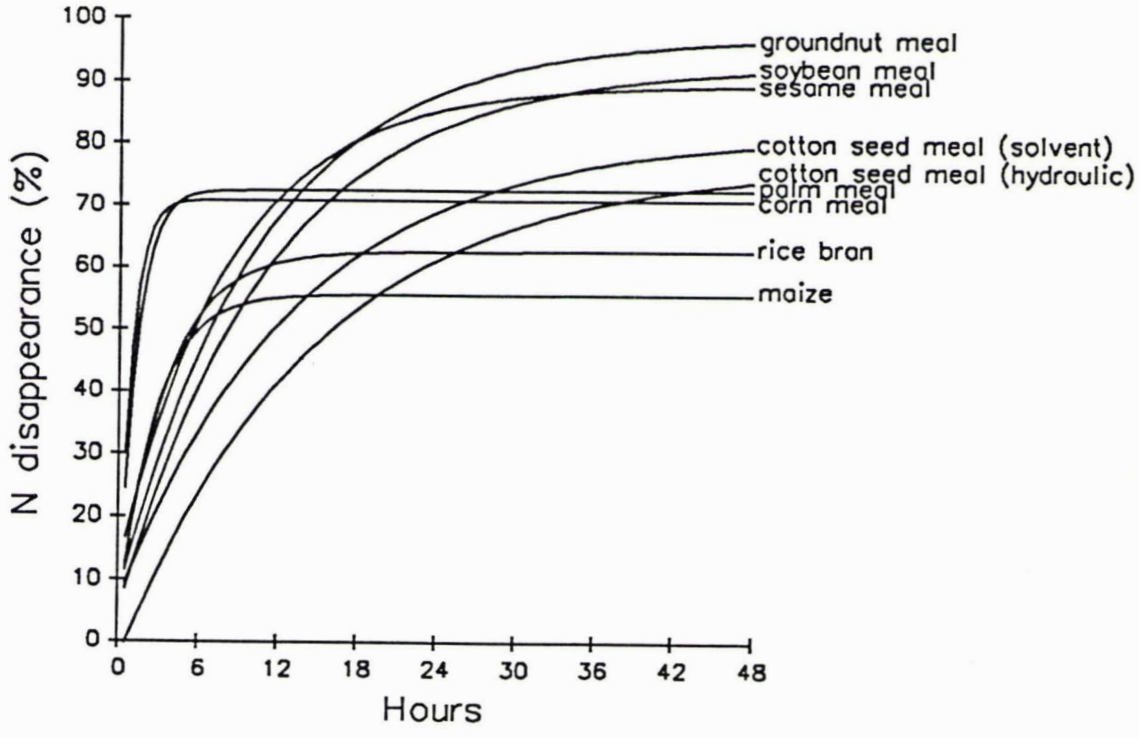

Figure 6.2 Curves drawn from fitted single exponential equation of percentage of N disappearance from the nylon bags of feedstuffs.

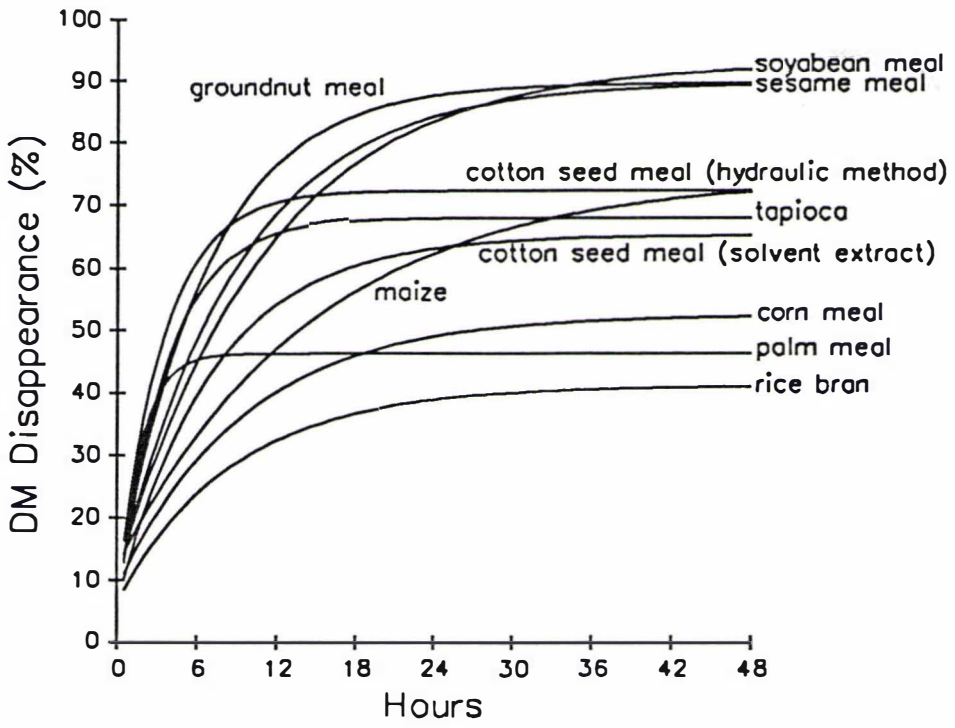

Figure 6.1 Curves drawn from fitted single exponential equation of percentage of DM disappearance from the nylon bags of feedstuffs.

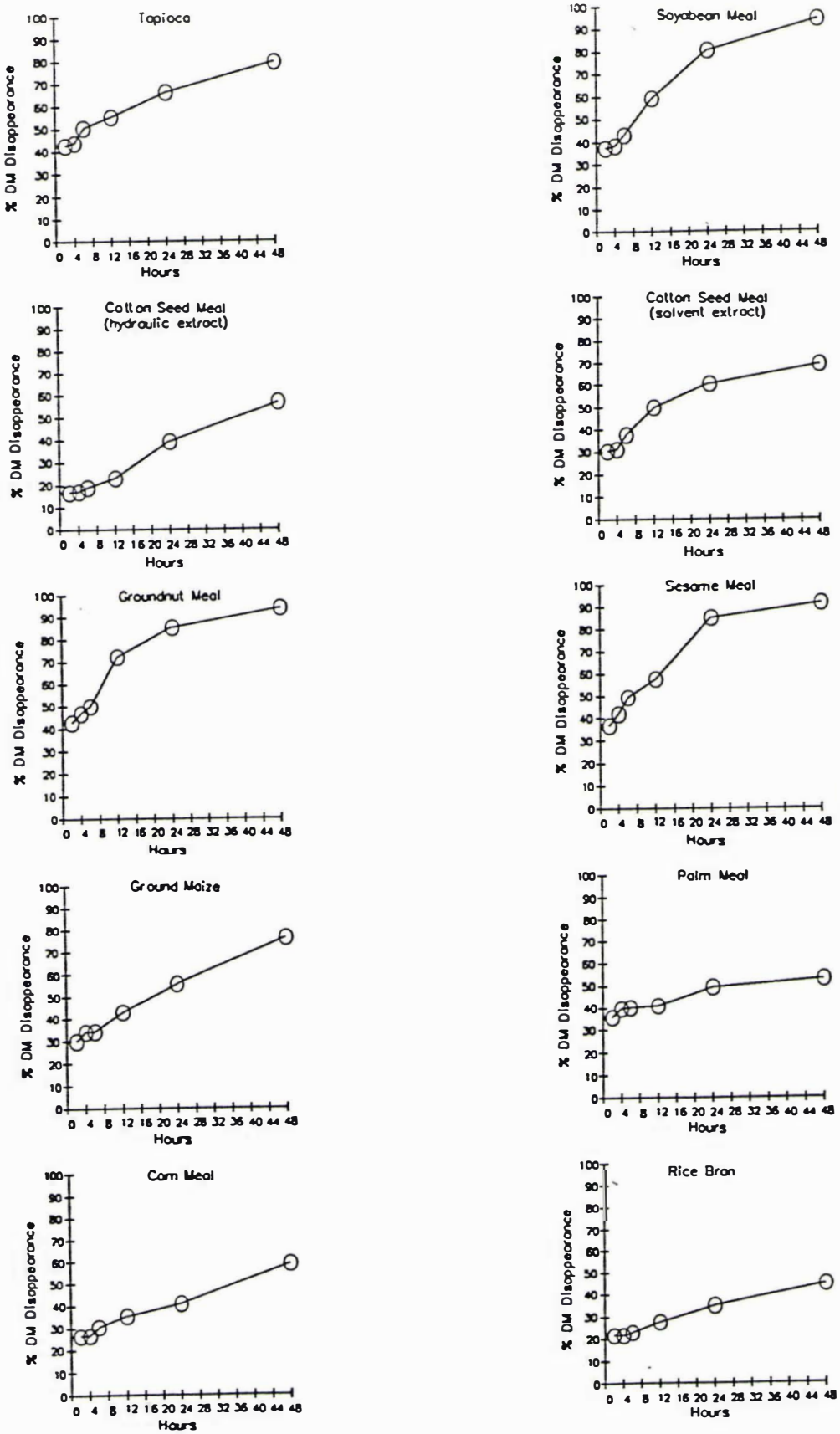

Figure 6.3 Percentage of DM disappearance from nylon bag at various time of incubation of individual feeds.

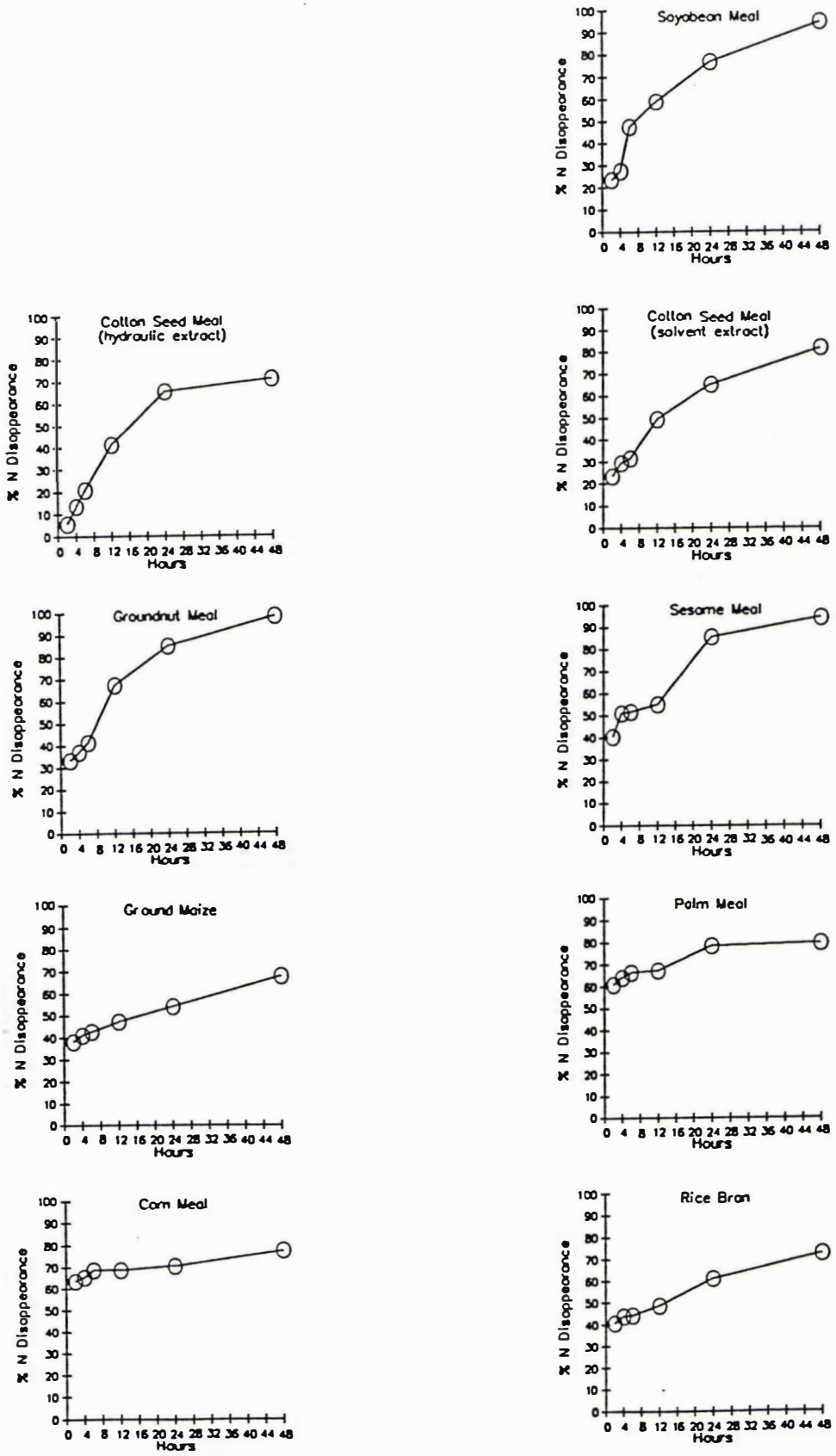

Figure 6.4 Percentage of N disappearance from nylon bag at various time of incubation of individual feeds.

6.4 DISCUSSION

6.4.1 FACTORS WHICH MAY AFFECT MEASUREMENTS

Ruminal degradation values were measured with repeated incubations up to 48 hours, and the degradation constants *a, b* and *c* were calculated. These constants are widely used to characterise the rumen degradation of feeds and they are closely correlated with *in vivo* DM intake, digestible DM intake and growth performance in sheep and cattle (Orskov and McDonald, 1979; Hovell *et al.*, 1986; Orskov *et al.*, 1988). However care must be taken with low degradable feeds to ensure that sufficient 'withdrawal' samples are taken over an adequate period of time, thereby providing sufficient data 'points' to adequately define the asymptote (*a+b*), as reported Orskov and McDonald (1979).

The animals in the present study were fed on a mixed diet at maintenance level and used a passage rate of 0.046/h which should have minimised the effect of basal diet on the degradability values. However, the composition of this ration may make it difficult to compare the present results with results obtained with animals fed on basal rations which were either solely concentrates or solely roughage. The relative effect of diet on nylon bag degradability makes it necessary to standardise the ration for the animals used for incubation. Loerch *et al.* (1983a) also found a significant but small effect of nitrogen source on the protein degradability. This could possibly be minimised by feeding small amount of a wide range of protein supplements to the animals used for incubation.

Although, the outflow rate in the present study was not measured, the calculation using an outflow rate of 0.046 was probably close to real values. However, the results should be interpreted with caution and used for the purpose of comparison between protein sources within the present experiment. Nevertheless, theoretical calculations were carried out to assess the effects of varying outflow rates over a wide range on estimates of protein degradability. The results displayed graphically in Figure 6.5 show that over the probable range of *k* for cattle given a mixed diet at maintenance (0.04-0.06), feed protein degradability will be altered by only 0.03-0.08 units. The results

further indicate that manipulations which increase *k*, e.g. increased level of feeding, are likely to have their greatest effects where *c*, the rate constant for disappearance of N from the nylon bag, is smallest.

For example, in the present study, *k* value is assumed to be 0.046/h. If comparisons were made between calculated *dg* values of cotton seed meal (solvent extract) with the smallest constant '*c*' (0.07) and of corn meal with the largest constant '*c*' (1.09), and if *k* value is increased from 0.046 to 0.08/h. The calculated *dg* values of the respective cotton seed meal (solvent extract) and corn meal were 41.5 and 66.0%. The differences between the assumption of *k* values of 0.046 and 0.08/h were 10.3 and 2% for cotton seed meal and corn meal respectively.

The choice of a suitable sample particle size is closely linked to the bag pore size used (Lindberg, 1985). In the light of the uncertainty as to the optimum pore size, the 47 μm pore size material selected for the present study was considered an acceptable compromise as most scientists widely accepted a pore size between 30 and 50 μm.

Effects of particle size were studied in the trial of Lindberg (1987), in which peas, rapeseed meal, wheat bran and oat hulls were ground either coarsely (5 mm screen) or finely (1.5 mm screen), and were incubated in 36 μm nylon bags in a rumen cannulated dairy cow. Only minor effects of sample particle size were reported. In the present study, the feed samples were ground through 3 mm screen, therefore, sample particle size should not have affected the results.

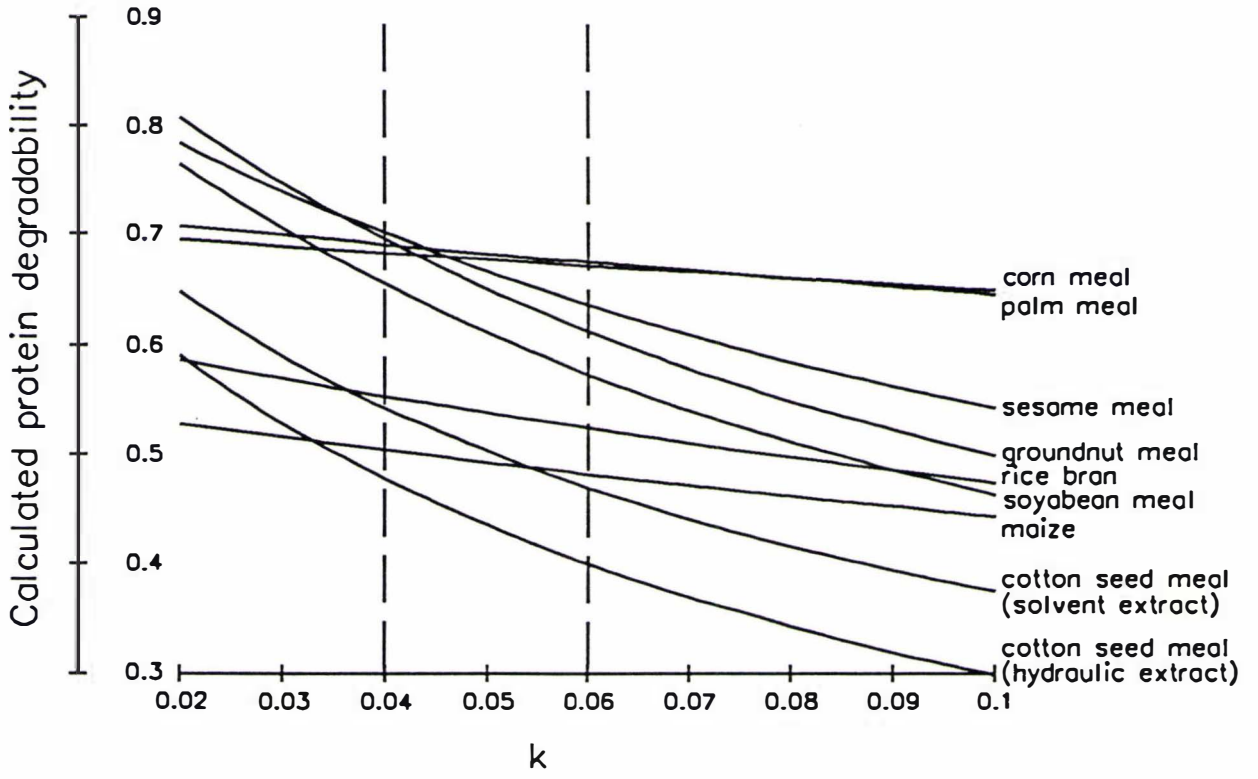

Figure 6.5 Calculated degradability value of feed protein at different fractional outflow rate. Dashed lines show the range most commonly measured outflow rate of feed protein.

6.4.2 DEGRADATION OF PROTEIN IN THE RUMEN

Table 6.4.1 shows the degradability values of protein for various feedstuffs classified in groups, from the present study and previous published data.

In the present study, the protein degradability value of soyabean meal (62.8%) was similar to those measured by Lindberg (1981a) and Rooke *et al.* (1982). The lower values of 35.6 and 36.3% reported by Okeke *et al.* (1983) compared with 82.0% reported by Siddons *et al.* (1985) were probably due to the smaller bag pore size of 10μm used in the former experiment compared with 43μm used in the latter experiment. Also the trial of Okeke *et al.* (1983) silage and concentrate was fed as a basal diet compared with hay in the trial of Siddons *et al.* (1985). Feeding concentrate has been found to reduce rumen pH (Mould and Orskov, 1983) and hence lower values of degradability would be expected (Lindberg, 1985).

The protein degradability values for cotton seed meal (45.1 and 51.8%) in the present study were similar to those recorded by Erdman *et al.* (1987), Hennessy *et al.* (1983), Goetsch and Owens (1985) and Barrio *et al.* (1986). The value for groundnut meal (66.8%) was similar to values measured by Siddons *et al.* (1985); and that for maize (49.7%) was similar to values measured by Barrio *et al.* (1986). The value of protein degradability for palm meal (68.6%) in the present study was higher than that recorded by Madsen and Hvelplund (1985) whereas the value of corn meal (68.0%) was similar to that recorded by Erdman and Vandersall (1983).

However, those values reported in Table 6.4.1 were determined in experiments which differed in several respects (different animal species, different basal diets, different bag pore size, different times of incubation and fractional outflow rates from the rumen of the solid particles). The differences in rate of degradation of various feedstuffs are likely to be due to differences between experiments in feed sources, sample preparation and ruminal suspension methods. The rate of protein degradation from various protein sources may be faster when the feedstuffs are incubated in the rumen of sheep given a high roughage-based diet as compared with high concentrate diets because of the faster rumen turnover on the high roughage-based diets where the cellulose digestion is rapid, compared with the high concentrate diets where cellulose digestion is slower. In addition, rates of degradation may be slightly lower when the diets are fed *ad libitum* than when they are given under restricted feeding conditions,

because of the enhanced rate of passage from the rumen at high levels of feeding. In fact, Orskov *et al.* (1980) observed that degradability decreased with increasing flow rates from the rumen, therefore, the ruminal passage rates have a major effect on the degradation of proteins. Care must be taken when compared the results in the present study with those reported in Table 6.4.1.

Although the present study was not designed to examine *in vivo* degradability of feed proteins, other authors have compared the *in situ* and *in vivo* measurements of feed protein degradability. For mixed diets and for diets with a large proportion of the nitrogen from protein supplements there appears, in general, to be a good agreement between estimates of protein degradability from nylon bag and *in vivo* methods (Mathers and Miller, 1981; Zinn *et al.*, 1981; Loerch *et al.*, 1983b; Kennedy *et al.*, 1982; Rooke and Armstrong, 1983; Stern and Satter, 1984; Siddons *et al.*, 1985; Madsen and Hvelplund, 1985; Rooke *et al.*, 1985). However, poor agreement between nylon bag and *in vivo* estimates has also been reported (Williams *et al.*, 1983; Lindberg, 1984; Rooke *et al.*, 1985). In diets consisting of roughages only, the estimates for protein degradability by nylon bag and *in vivo* have been shown to differ considerably (Chapman and Norton, 1984; Kennedy *et al.*, 1984) and may be due to errors involved in the estimation of protein degradability by the nylon bag technique (Kennedy *et al.*, 1984; Varvikko and Lindberg, 1985). In cows fed on hay, Madsen and Hvelplund (1985) found that the best relation between *in vivo* and nylon bag degradabilities was obtained when using a relatively high outflow rate (0.08/h) for cows eating about 14 kgDM/day.

In heifers fed on a mixed diet in the present study and assuming value of 0.046/h fractional outflow rate, the *dg* values by nylon bag technique were similar to those *in vivo* values obtained from cattle reported in Table 6.4.1. For example, the *dg* values for cotton seed meal were 45.1 and 51.8 compared to *in vivo* value of 53.0% (Madsen and Hvelplund, 1985) and of 54.0% (Zinn and Owens, 1983). The *dg* value for soybean meal was 62.8 compared to *in vivo* value of 65.0% (Madsen and Hvelplund, 1985). The *dg* value for groundnut meal was 66.8 compared to *in vivo* value of 63.0% (Hume, 1974). This suggested that for cattle fed at maintenance on a mixed diet, a close relation between *in vivo* and nylon bag degradabilities could be obtained when using an outflow rate of about 0.05/h. The outflow rate values of 0.046 and 0.05 were also suggested by Orskov and McDonald (1979) and ADAS (1989).

The variations in protein degradabilities recorded in this chapter provides an explanation of the variations in RDP and UDP supplies to the animals from various formulations of concentrates used in the present studies (Chapters 4 and 5) and in Thailand. For example, the protein degradabilities of 17% CP and 30% CP concentrates used in Chapter 4 were estimated to be 0.65 and 0.53 respectively while those (22% CP concentrates) in Chapter 5 were estimated to range from 0.57 to 0.68. The high protein degradabilities of the 17% CP concentrate (0.65) recorded in Chapter 4 and of the 22% CP Concentrate 3 (0.68) reported in Chapter 5 were due to the addition of 2% urea to these concentrates. In contrast, the low protein degradabilities of the 30% CP concentrates (0.53) recorded in Chapter 4 and of the 19% CP Concentrate 1 (0.57) reported in Chapter 5 were due to the considerable proportion of cotton seed meal and maize, which are known to be resistant to rumen degradation, in these concentrates.

From the two experiments conducted in Thailand (Chapters 4 and 5), there was no clear advantage in using either low or high protein degradabilities concentrates. It appeared however that Concentrate 2 (22% CP concentrate with a protein degradability value of approximately 0.60 with 1% urea added) showed the most favourable responses in terms of increased roughage intake and animal performance (milk yield and liveweight gain).

With low quality roughage, as often occurs in the Tropics, a major difficulty with the efficient use of concentrates by ruminants is that as the amount of concentrate eaten increases, the intake of roughage decreases i.e. substitution of concentrate for roughage occurs. Secondly, the digestion of the fibrous components or cell wall contents of the diet may be depressed by the dietary concentrates. Both of these factors tend to reduce the amount of digestible energy the animal obtains from the roughage. It may be more desirable for some of the dietary concentrates to be digested and absorbed from the small intestines as well as the appropriate proportion being fermented in the rumen. However, rumen fermentable N and carbohydrates are also required by fibre-digesting rumen microorganisms and a balance of these nutrients, such as in Concentrate 2 (Chapter 5) should be taken into account when concentrate formulations are made.

Most cereal grains and their by-products contain large proportions of starch and sugar which are rapidly fermented in the rumen. Urea is known to degrade to ammonia very rapidly. Maize, sorghum and cotton seed meal are only slowly fermented in the rumen and appreciable proportions may escape rumen fermentation (Sutton, 1980). Also considerable amounts of starch in rice bran have been reported to reach the duodenum of cattle (Elliot *et al*, 1978). Hopefully, knowledge of such variations in degradation of feedstuffs mentioned earlier and reported in this chapter will help the farmers and the government agricultural advisers to formulate an appropriate concentrate for the particular classes of stock and hence contribute to the progress of Thai dairy industry.

6.5 CONCLUSION

1. Estimations of protein degradability for feedstuffs commonly used in the concentrates which are fed to dairy cattle in Thailand provided useful information for prediction of protein supply to the animal (both by microbial protein and dietary protein which escaped rumen degradation).

2. The estimates of protein degradation of feedstuffs listed from other published experiments are extremely variable and *in vivo* information is very limited and often nonexistent for many feedstuffs. Part of the variation between degradation estimates is due to variation in experimental methods. The values for protein degradation in Table 6.4.1 must be used with caution. Soyabean meal, groundnut meal, sesame meal, palm meal and corn meal contain relatively high concentrations of degradable protein (63-69%) while cotton seed meal and maize (45-52%) are relatively resistant to protein degradation.

3. Knowledge of variations in protein degradability between feeds is essential for the appropriate formulation and preparation of meal concentrates for the various classes of animals (dry, milking or young stock). Such information is very limited in Thailand and the present values may help to explain the variation that currently occurs in the performance of cattle fed on different concentrates in Thailand. More basic research of the value of the various feeds available in Thailand is urgently needed.

Table 6.4.1 Values for protein degradability; the present values and published estimates of protein disappearance from nylon bags incubated in the rumen.

Sample	Animal	Basal diet	Bag pore size (μm)	Hour of incuba -tion	*k*	*dg* (%)	References
Soyabean meal	**Cattle**	**Treated straw + concentrate**	**41**	**48**	**0.046**	**62.8**	**The present study**
	Sheep	Barley	15	24	0.030	66.0	Ganev *et al.*, 1979.
	Sheep	Barley	15	24	0.067	57.0	
	Sheep	Dried grass	15	24	0.046	71.0	
	Sheep	Dried grass	15	24	0.060	66.0	
	Cattle	Silage + concentrate	67	28	0.048	67.0	Erdman *et al.*, 1987.
	-	-	-	24	0.050	86.0	Laycock and Miller, 1981.
	Cattle	Hay	10	48	0.050	66.0	Lindberg, 1981a.
	Cattle	Hay + oats (70:30)	10	48	0.050	56.6	
	Cattle	Hay + oats (30:70)	10	48	0.050	57.2	
	Cattle	Hay + oats (30:70)	10	48	0.050	53.8	Lindberg, 1981b.
	Cattle	Hay + oats (70:30)	10	48	0.050	57.0	
	Cattle	Hay + oats (30:70)	10	48	0.100	43.5	
	Cattle	Hay + oats (70:30)	10	48	0.100	43.6	
	Cattle	Hay	36	48	0.044	73.0	Kristensen *et al.*,1982.
	Cattle	Hay + barley	47	24	0.130	40.0	Rooke *et al.*, 1982.
	Cattle	Hay + barley	47	24	0.046	59.0	
	Cattle	Hay + barley	47	24	0.036	65.0	

Cattle	Silage + concentrate	47	24	0.036	80.0	Rooke *et al.*, 1983.
Sheep	Hay	53	24	0.050	92.1	Cronje, 1983.
Cattle	Hay + concentrate (25:75)	52	24	0.055	64.9	Weakley *et al.*, 1983.
Cattle	Hay + concentrate (40:60)	52	24	0.055	71.3	
Cattle	Hay + concentrate (60:40)	52	24	0.055	69.3	
Cattle	Hay + concentrate (80:20)	52	24	0.055	71.7	
Cattle	Hay + concentrate	52	24	0.049	63.0	Stern *et al.*, 1983.
Cattle	Hay + concentrate	52	24	0.049	72.0	
Cattle	Hay + concentrate	52	24	0.049	78.0	
Cattle	Hay + concentrate	52	24	0.049	84.0	
Cattle	Hay	36	48	0.080	60.0	Madsen and Hvelplund., 1985.
Cattle	Hay	20	15	0.070	52.0	Hennessy *et al.*, 1983.
Cattle	Concentrate	20-70	24	0.052	71.3	Loerch *et al.*, 1983a.
Sheep	Dried grass	36	24	0.100	84.8	Orskov *et al.*, 1983.
Sheep	Dried grass	36	24	0.050	62.2	
Sheep	Barley	36	24	0.050	54.8	
Cattle	Dried grass	36	24	0.100	89.2	
Cattle	Silage + concentrate	67	46	0.05	67.5	Erdman and Vandersall. 1983.
Cattle	Silage + concentrate	10	24	0.082	35.6	Okeke *et al.*, 1983.
Cattle	Silage + concentrate	10	24	0.082	36.3	
Cattle	Hay + concentrate	48	24	0.050	72.3	Ha and Kennelly. 1984.
Cattle	Hay + concentrate (60:40)	52	24	0.050	74.5	Stern *et al.*, 1985.

Cattle	Silage + concentrate	59	72	0.050	83.0	Armentano *et al.*, 1986.
Cattle	Hay + concentrate	48	24	0.050	53.5	Ha *et al.*, 1986.
Cattle	Hay + concentrate	50-70	72	0.103	71.3	Zerbini and Polan., 1985.
Sheep	Hay	43	48	0.034	82.0	Siddons *et al.*, 1985.
				0.046	71.0	Orskov and McDonald, 1979.
Cattle	Lucerne + concentrate	20-70	24	-	89.3	Loerch *et al.*, 1983b.
Cattle	Hay + concentrate	48	24	-	82.0	Zinn *et al.*, 1981.
Cattle	Hay + concentrate	48	24	-	85.0	
Cattle	Roughage + concentrate	10	24	-	63.6	Forster *et al.*, 1983.
Cattle	Silage	10	24	-	83.2	Varvikko *et al.*, 1983.
Cattle	Silage	40	24	-	84.7	
Sheep	Grass (poor quality)	43	24	-	99.0	Siddons and Paradine. 1983.
Sheep	Grass + barley	43	24	-	98.0	
Sheep	Grass (good quality)	43	24	-	98.0	
Sheep	Grass + barley	43	24	-	84.0	
Cattle	Grass (poor quality)	43	24	-	96.0	
Cattle	Grass + barley	43	24	-	84.0	
Cattle	Grass (good quality)	43	24	-	84.0	
Cattle	Grass + barley	43	24	-	72.0	
Cattle	Silage + concentrate	20-70	24	-	89.0	Spears *et al.*, 1985.
Cattle	Hay + concentrate	25-75	20	-	73.9	Goetsch and Owens, 1985.
Sheep	Straw + concentrate	24	24	-	51.5	Alawa and Hamingway. 1986.

	Cattle	Silage + concentrate	47	24	-	79.0	Rooke *et al.*, 1986.
	Sheep	Hay + concentrate	70	24	-	81.8	Waltz and Loerch, 1986.
	Sheep	Hay + concentrate	70	24	-	84.3	
	Cattle	Straw + concentrate	24	24	-	53.9	Alawa *et al.*, 1986.
	Cattle	Roughage + concentrate	70	24	-	50.5	Kovacik *et al.*, 1986.
	Cattle	-	45	12	-	54.4	Rae and Smithard, 1985
	Cattle	Hay + concentrate (20:80)	50-75	24	-	68.6	Barrio *et al.*, 1986.
	Cattle	Hay + concentrate (60:40)	50-75	24	-	68.8	
In vivo	Cattle					73.0	Zinn *et al.*, 1981.
	Sheep					39.0	Hume, 1974.
	Cattle					76.0	Merchen *et al.*, 1979.
	Cattle					80.0	Kropp *et al.*, 1977.
	Cattle					66.0	Zinn and Owens, 1983.
	Cattle					71.0	Loerch *et al.*, 1983b.
	Cattle					65.0	Madsen and Hvelplund, 1985.
	Cattle					74.0	Rooke *et al.*, 1982.
	Cattle					90.0	Rooke *et al.*, 1983.
	Sheep					88.0	Siddons *et al.*, 1985.

Cotton seed meal	**Cattle**	**Treated straw + concentrate**	**41**	**48**	**0.046**	**45.1**	**The present study (Solvent extracted)**
	Cattle	**Treated straw + concentrate**	**41**	**48**	**0.046**	**51.8**	**The present study (hydraulic extracted)**
	Cattle	Hay + oats (70:30)	10	24	0.050	30.2	Lindberg, 1981.
	Cattle	Hay + oats (30:70)	10	24	0.050	31.6	
	Cattle	Hay + oats (70:30)	10	24	0.100	28.4	
	Cattle	Hay + oats (30:70)	10	24	0.100	30.0	
	Cattle	Hay	36	48	0.044	73.0	Kristensen *et al.*, 1982.
	Cattle	Hay	36	48	0.080	56.0	Madsen and Hvelplund., 1985.
	Sheep	Lucerne chaff	47	24	0.027	83.0	Sriskandarajah and Kellaway, 1982.
	Cattle	Silage + concentrate	67	28	0.049	54.2	Erdman *et al.*, 1987.
	Sheep	Dried grass	36	24	0.100	83.0	Orskov *et al.*, 1983.
	Sheep	Dried grass	36	24	0.050	69.7	
	Sheep	Barley	36	24	0.050	58.7	
	Cattle	Dried grass	36	24	0.100	78.4	
	Cattle	Silage + concentrate	67	46	0.050	36.5	Erdman and Vandersall, 1983.
	Cattle	Hay	20	15	0.070	46.0	Hennessy *et al.*, 1983.
	Sheep	Hay	53	24	0.050	60.5	Cronje, 1983.
	Cattle	Hay + concentrate	25	48	0.050	63.0	DePeters and Bath, 1986.
	Cattle	Hay + concentrate	50-70	72	0.083	71.1	Zerbini and Polan, 1985.

	Cattle	Hay + concentrate (20:80)	50-75	24	0.060	62.4	Barrio *et al.*, 1986.
	Cattle	Hay + concentrate (20:80)	50-75	24	0.030	52.1	
	Cattle	Hay + concentrate (60:40)	50-75	24	0.060	59.8	
	Cattle	Hay + concentrate (60:40)	50-75	24	0.030	48.7	
	Cattle	Hay + concentrate	48	24	-	39.0	Zinn *et al.*, 1981.
	Cattle	Hay + concentrate	48	24	-	76.0	
	Cattle	Hay + concentrate	25-75	20	-	45.8	Goetsch and Owens, 1985.
	Cattle	Hay + concentrate	25-75	20	-	47.9	
	Sheep	Grass (poor quality)	43	24	-	93.0	Siddons and Paradine, 1983.
	Sheep	Grass + barley	43	24	-	90.0	
	Sheep	Grass (good quality)	43	24	-	92.0	
	Sheep	Grass + barley	43	24	-	86.0	
	Cattle	Grass (poor quality)	43	24	-	89.0	
	Cattle	Grass + barley	43	24	-	83.0	
	Cattle	Grass (good quality)	43	24	-	86.0	
	Cattle	Grass + barley	43	24	-	82.0	
In vivo	Cattle					39.0	Zinn *et al.*, 1981.
	Cattle					54.0	Zinn and Owens, 1983.
	Cattle					53.0	Madsen and Hvelplund, 1985.
Groundnut meal	**Cattle**	**Treated straw + concentrate**	**41**	**48**	**0.046**	**66.8**	**The present study**
	Sheep	Barley	15	24	0.030	82.0	Ganev *et al.*, 1979.
	Sheep	Barley	15	24	0.067	72.0	
	Sheep	Dried grass	15	24	0.046	75.0	
	Sheep	Dried grass	15	24	0.060	70.0	

	Cattle	Hay + concentrate	52	24	0.040	79.6	Stern and Satter, 1984
	Cattle	Hay + concentrate	52	24	0.040	76.4	
	Cattle	Hay + concentrate	52	24	0.040	73.6	
	Sheep	Hay	53	24	0.050	93.2	Cronje, 1983.
	Sheep	Dried grass	36	24	0.100	96.1	Orskov *et al.*, 1983.
	Sheep	Dried grass	36	24	0.050	68.9	
	Sheep	Barley	36	24	0.050	56.8	
	Cattle	Dried grass	36	24	0.100	93.6	
	Sheep	Hay	43	48	0.038	67.0	Siddons *et al.*, 1985.
	Sheep	Grass (poor quality)	43	24	-	93.0	Siddons and Paradine. 1983.
	Sheep	Grass + barley	43	24	-	78.0	
	Sheep	Grass (good quality)	43	24	-	89.0	
	Sheep	Grass + barley	43	24	-	53.0	
	Cattle	Grass (poor quality)	43	24	-	86.0	
	Cattle	Grass + barley	43	24	-	65.0	
	Cattle	Grass (good quality)	43	24	-	70.0	
	Cattle	Grass + barley	43	24	-	54.0	
In vivo	Cattle					63.0	Hume, 1974.
	Cattle					83.9	Stern and Satter, 1984.
	Sheep					76.0	Siddons *et al.*, 1985.
Maize	**Cattle**	**Treated straw + concentrate**	**41**	**48**	**0.046**	**49.7**	**The present study**
	Sheep	Hay	53	24	0.050	64.2	Cronje, 1983.

	Cattle	Silage + concentrate	67	46	0.050	70.3	Erdman and Vandersall, 1983.
	Sheep	Concentrate	55	12	0.033	60.8	Meyer *et al.*, 1986.
	Cattle	Silage + concentrate	67	28	0.044	61.4	Erdman *et al.*, 1987.
	Cattle	Hay + concentrate (20:80)	50-75	24	0.06	51.8	Barrio *et al.*, 1986.
	Cattle	Hay + concentrate (20:80)	50-75	24	0.03	45.6	
	Cattle	Hay + concentrate (60:40)	50-75	24	0.06	49.5	
	Cattle	Hay + concentrate (60:40)	50-75	24	0.03	42.1	
	Cattle	Hay + concentrate	50-70	72	0.070	69.4	Zerbini and Polan., 1985.
	Cattle	Hay	36	48	0.080	31.0	Madsen and Hvelplund., 1985.
	Sheep	Hay	48	20	-	55.0	Orskov and Mehrez, 1977.
	Sheep	Concentrate	48	36	-	53.6	Mehrez and Orskov, 1977.
	Cattle	Roughage + concentrate	10	24	-	60.4	Forster *et al.*, 1983.
In vivo	Cattle					35.0	Zinn and Owens, 1983.
Palm meal	**Cattle**	**Treated straw + concentrate**	**41**	**48**	**0.046**	**68.5**	**The present study**
	Cattle	Hay	36	48	0.080	34.0	Madsen and Hvelplund, 1985.
Corn meal	**Cattle**	**Treated straw + concentrate**	**41**	**48**	**0.046**	**68.0**	**The present study**
	Cattle	Silage + concentrate	67	46	0.050	70.0	Erdman and Vandersall, 1983.

Values with no rate constants for rumen turnover of concentrate (k) are referred as 'potential degradability', whereas values with rate constants (k) are referred as 'effective degradability' (See Orskov and Mehrez, 1977), and *in vivo* values indicated.

CHAPTER 7

A STUDY OF THE EFFECT OF THE DEGRADABILITY OF PROTEIN IN CONCENTRATE SUPPLEMENTS FOR SHEEP FED ON LOW QUALITY ROUGHAGE UNDER MILD OR HOT CONDITIONS

7.1 INTRODUCTION AND OBJECTIVES

The main limitations to the use of forage in the tropics are its extremely low protein content,digestibility and intake (Hamilton *et al.*, 1970; Minson, 1980). Ruminants fed solely on low quality roughage have a marked deficiency of rumen fermentable nitrogen which is one of the reasons for reduced feed intake (Campling *et al.*, 1962), due to a reduced rate of microbial activity in the rumen. In Chapter 4, it was shown that a higher animal performance (milk and liveweight gain) was associated with intermediate ratios of rumen degradable protein to metabolisable energy intake (RDP/ME, about 8.5 gRDP/MJME). The efficiency of use of 'estimated' ME appeared higher but the mechanism involved was not clear from the parameters measured. For example the digestibility of the ration rather than the efficiency of ME utilisation per se may have differed, because ME intakes were estimated from *in vitro* determinations of digestibility.

Supplying rumen degradable protein (often from urea) in the concentrate to maintain moderate levels of ammonia concentration in the rumen (150-200 mgNH_3-N/litre; Leng and Nolan , 1984) should increase the rate and extent of digestion, and hence optimise intake, and increase microbial protein yield relative to volatile fatty acid production (Preston and Leng, 1987).

In addition to poor quality forages, ruminants in the tropics may be subject to high temperatures which can reduce production (Preston and Leng, 1987). Farm animals are homeothermic animals and they attempt to maintain a constant deep body temperature of approximately 37°C. Heat stress affects an animal's metabolism by causing a reduction in food intake (O'Kelly, 1988). Depressed appetite is linked with many physiological and endocrinological adjustments to reduce heat generated during ruminal fermentation and body metabolism. Reduced food consumption during heat stress may also be associated with deficiencies of essential nutrients. In addition, animals exposed to high temperature (eg. 32°C) showed increased body temperature, urinary nitrogen loss and fat excretion in the faeces (O'Kelly, 1988).

The present experiment examined the effect of feeding concentrates which differed in protein degradability (by inclusion of urea) to sheep fed on low quality hay under 'mild' and 'hot' conditions. This experiment tried to determine the optimum level of urea (0, 1 and 2%) in concentrates at two enviromental temperatures and the interaction between protein degradability and temperature by measuring the effects on:

1. Voluntary food intake.
2. Digestibility of total ration (*in vivo*).
3. Nitrogen balance.
4. Rumen pH, rumen ammonia concentration and VFA production in the rumen.
5. Feed degradation in the rumen.

7.2 MATERIALS AND METHODS

7.2.1 ANIMALS AND TREATMENTS

Initially, 8 rumen-fistulated sheep fed on hay and concentrates were randomly assigned into two blocks of a 4 x 4 Latin Square Design with 4 sheep and 4 levels of urea inclusion in the concentrates. However, two sheep (on the 3% urea concentrate) became sick after one month of the experiment and the treatments were re-arranged into two blocks of a 3 x 3 Latin Square Design, one for a high temperature and another for a mild temperature. The experiment was then re-started with the treatments as follows:

	Ambient Temperature					
	13-18°C Mild			29-32°C Hot		
Sheep No.	1	2	3	4	5	6
Period 1	0%	1%	2%	2%	0%	1%
Period 2	1%	2%	0%	0%	1%	2%
Period 3	2%	0%	1%	1%	2%	0%

% urea in the concentrates
Each period lasted 20 days

7.2.2 ANIMALS AND MANAGEMENT OF THEIR FEEDING

Adjustment period

Before the start of the experiment, animals were housed individually in metabolic crates, under natural ambient conditions of temperature (13-18°C, 80%RH). Chaffed meadow hay which was similar in nutritive value to pastures commonly used in Thailand (9-11% CP, 50-60% DMD; Chapter 4) was fed in increasing quantities until maximum intake was obtained and maintained. A mixture of equal proportions of the 3 concentrates was also fed in increasing quantities until each sheep ate the required amount of 300 gDM concentrate/day which together with the expected intake of 900 gDM hay gave a ratio of concentrate to hay of 1:3 as in the previous experiment (Chapter 4).

After two weeks of the adjustment period, one group of sheep was moved into a controlled temperature room which was controlled at approximately 32°C whereas the ambient temperature group was kept at 13 to 18°C. The feeding of concentrates and hay were continued throughout the experiment of 60 days. Measurements were made over the last 10 days of each 20 day-period.

One batch of meadow hay was purchased in bulk, to cover the feeding requirements throughout the experimental period, and to avoid any fluctuations in the chemical composition of the diet. The hay was chaffed through a chaff-cutter, and reduced to 40-80 mm length.

The 3 concentrates contained approximately 25% CP in order that the total ration (concentrate plus hay) would have a crude protein percentage close to 15%, similar to the level recommended for dairy cows in Thailand (NRC, 1985).

The 3 types of concentrates used were mixed separately as the following formulation.

Table 7.2.1 The individual component of the three concentrates.

Component	Concentrates		
	0% urea	1% urea	2% urea
Brewers' grain	50	50	50
Soyabean meal	25	15	5
Barley meal	10	14	18
Maize meal	10	15	20
Molasses	5	5	5
Urea	0	1	2

7.2.4 MEASUREMENTS

7.2.4.1 Voluntary Food Intake

All sheep were offered the hay *ad libitum* throughout the experiment, and concentrates were fed at 300 gDM/sheep daily, divided into two equal meals. The concentrates and hay were fed twice daily at 0700 and 1600 h. The sheep were allowed access to the concentrates for 30 minutes at each feeding time. The refused concentrates were weighed and dried. The first 10 days of each period were used as the adaptation period. Voluntary food intake (VFI) was recorded over the next 10 days. Representative samples of the feed offered were taken daily, and DM determined on duplicate 100 g samples in a forced draught oven at 80°C for 36 hours. Two further 100 g samples were taken daily, and pooled separately at -20°C. They were subsequently used for laboratory analysis.

7.2.4.2 Digestibility Trial

During the 10 day digestibility trial (the final 10 days of each period), the weights of oven dried feed offered, feed refusals and faecal outputs were recorded. The refusals for each animal were collected daily, weighed and pooled for two 5-day periods and stored at 4°C, and the DM was determined after the 5-day period. The faeces from each animal were bulked for each of two 5-day periods and kept at -20°C. At the end of each period, the faeces were allowed to thaw and were mixed thoroughly. Two 1000 g subsamples were taken for DM determination in a forced draught oven at 80°C until constant weight had been attained (approximately 72 hours).

The subsamples of feed offered, total feed refusals per animal and total faecal output per animal were bulked over the 5-day period and stored at -20°C, and subsequently freeze-dried, ground and stored for chemical analysis.

Urine was collected from each animal over the two 5-day digestibility trials. It was collected in 100 ml of 25% (v/v) sulphuric acid. The pH of the urine was kept below 3, to prevent any loss of ammonia. The urine from each animal was bulked over two 5-day periods, and stored at -20°C for subsequent total N determination (Kjeltec Auto 1030 Analyser).

7.2.4.3 Feed Degradation Rates

Samples of each type of concentrate and hay were taken and later analysed for dry matter (DM), total fiber, and total nitrogen.

The rate of degradation of the feeds (DM and protein) was assessed by use of the Nylon Bag Technique (Orskov and McDonald, 1979) and as previously been described in Chapter 6 of this thesis. One hundred and twenty six nylon bags (10 x 14 cm, 47 µm, Estal Mono, Switzerland) each containing approximately 5 gm of ground (3 mm sieve) feed samples of one of three types of concentrates or hay (24 bags per type of concentrates and 54 bags of hay) were prepared. Four bags per type of concentrates

and 3 bags of hay were suspended in the rumen of six fistulated sheep (7 bags per sheep in total) in each period (3 periods). One bag of concentrate was withdrawn from the rumen at 2, 6, 12 and 24 hour and one bag of hay at 12, 24 and 48 hour after incubation as shown in Table 7.2.2. Details of the bags in the rumen of experimental sheep are presented in Table 7.2.3.

Table 7.2.2 Time of withdrawal of the bags containing concentrate or hay.

Type of sample:	Hour of withdrawal
Concentrate	2, 6, 12, and 24
Hay	12, 24, and 48

After withdrawal, samples were washed in running water until the water ran clear. They were then freeze-dried and subjected to dry matter (DM), and total nitrogen analyses.

7.2.4.4 Rumen Fluid

7.2.4.4.1 Collection of samples

Rumen fluid samples were taken through a rumen sampler (a tube with gauze on end) inserted through the fistula. The samples were taken on day 7 during the digestibility trial (on day 17 of each 20-day period) at 0 (before concentrate feeding), 3, 5, and 7 hours after the feeding of concentrates in the morning (at 0800am).

Table 7.2.3 Details of nylon bags suspended in the rumen of sheep in feed degradation trial.

	Temperature Conditions					
	13-18°C			28-32°C		
	Sheep No.					
	1	2	3	4	5	6
Period 1	4 bags 0% urea 3 bags of hay	4 bags 1% urea 3 bags of hay	4 bags 2% urea 3 bags of hay	4 bags 2% urea 3 bags of hay	4 bags 0% urea 3 bags of hay	4 bags 1% urea 3 bags of hay
Period 2	4 bags 1% urea 3 bags of hay	4 bags 2% urea 3 bags of hay	4 bags 0% urea 3 bags of hay	4 bags 0% urea 3 bags of hay	4 bags 1% urea 3 bags of hay	4 bags 2% urea 3 bags of hay
Period 3	4 bags 2% urea 3 bags of hay	4 bags 0% urea 3 bags of hay	4 bags 1% urea 3 bags of hay	4 bags 1% urea 3 bags of hay	4 bags 2% urea 3 bags of hay	4 bags 0% urea 3 bags of hay

7.2.4.4.2 Ammonia concentration

The samples of rumen fluid (20 ml each) were added to 5 ml of deproteinising reagent (1M sulphuric acid, saturated with magnesium sulphate), centrifuged at 1895 g for 15 minutes, and stored at -20°C until analysis by the Kjeldahl method (Kjeltec Auto 1030 Analyser).

7.2.4.4.3 pH

The pH of rumen fluids were measured immediately on fresh samples by a pH meter (PHM61, Laboratory pH Meter, Radiometer, Copenhagen), after calibration with pH 7.0 and pH 4.0 buffers.

7.2.4.4.4 Volatile fatty acids

Duplicate samples (5 ml) were added to 1 ml of protein precipitant (metaphosphoric acid/formic acid: 18.75% w/v / 25% v/v). One ml of the internal standard (isocaproic acid: 0.52% v/v) was added to one sample (internal standard sample), and 1 ml of distilled water was added to the other sample (control sample). Both samples were centrifuged at 1895 g for 15 minutes and stored at -20°C until analysis. The concentrations of individual VFAs were measured by Gas Chromatoghraphy (HRGC-5300 Mega Senes, Carto Erba Instruments).

7.2.5 STATISTICAL ANALYSIS

All data were analysed using the Statistic Analysis System (SAS) computing package (SAS Institute Inc., Cary, NC 27512-8000, USA. 1985,86,87).

The statistical model used to defined the mean values is given in Appendix 4.4. Variables were analysed for effects of temperature, urea, period, sheep and temperature x urea interaction. Temperatures were tested against sheep within temperatures. Urea, period, sheep and interaction were tested against residual mean squares.

Those parameters, rumen pH, ammonia concentration and volatile fatty acids, measured in time series were also analysed using repeated measurement analysis described in Appendix 4.5.

As the number of animals used in the present study was small, a significant level of 90% confidence ($p<0.10$) was used where appropriate.

7.3 RESULTS

7.3.1 ENVIRONMENT AND BODY TEMPERATURE

Environmental conditions including ambient temperatures and relative humidities during the experimental period are illustrated in Figure 7.1. Mean values for rectal temperature and respiration rate of the sheep held in both environmental conditions are shown in Table 7.3.1. Sheep held in hot temperature had higher values for rectal temperature ($p<0.01$) and respiration rate ($p<0.001$) than sheep held in mild temperature.

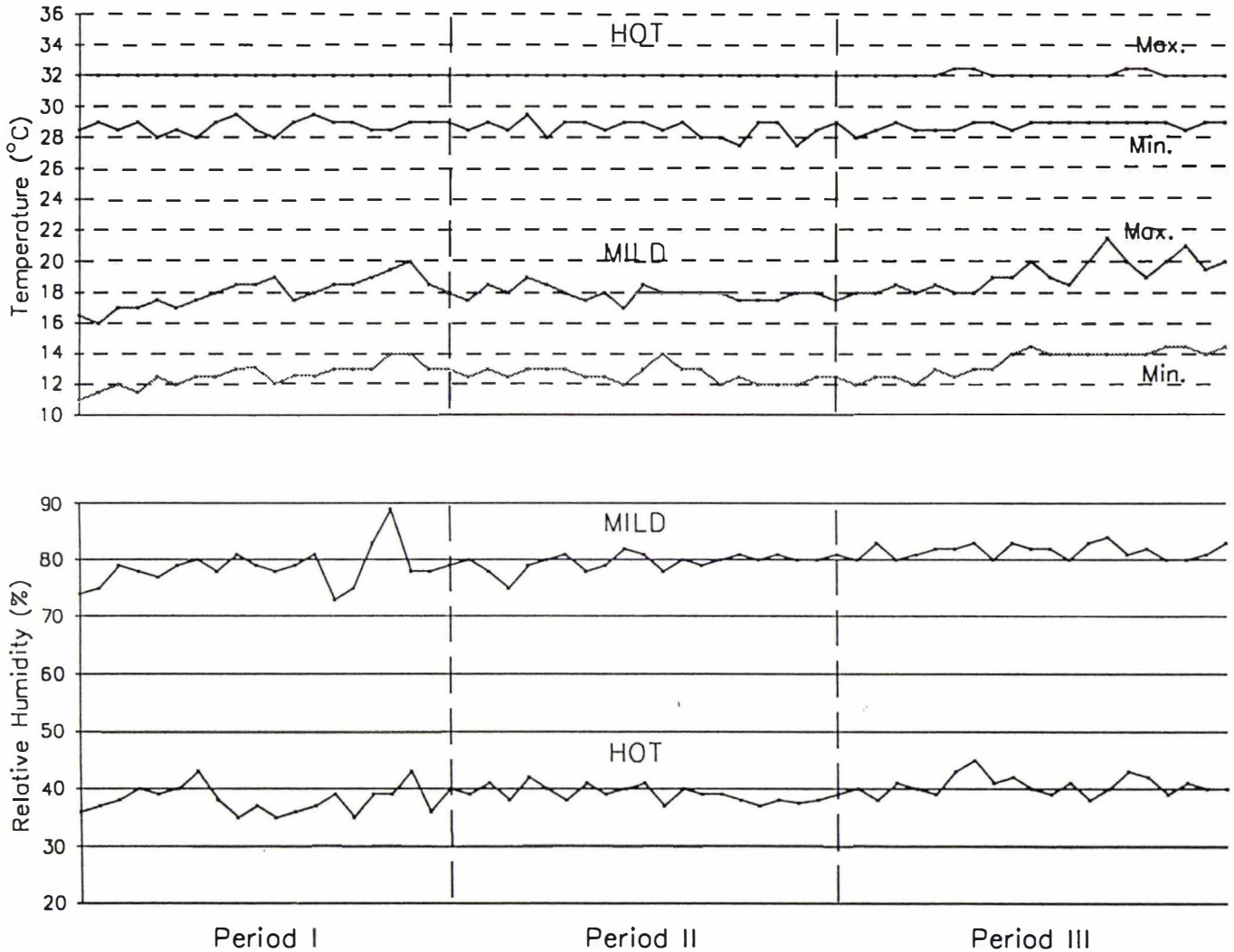

Figure 7.1 Daily maximum and minimum temperatures, and relative humidity under mild and hot conditions over the experimental period.

Table 7.3.1 Rectal temperature and respiration rate of sheep held at mild and hot environment.

Days	0-10	11-20	21-30	31-40	41-50	50-60	MEAN
RECTAL TEMPERATURE (°C)							
Mild							
Sheep 1	38.7	38.8	38.8	38.8	38.8	38.6	38.7
Sheep 2	38.3	38.6	38.5	38.6	38.5	38.8	38.5
Sheep 3	38.4	38.5	38.7	38.6	38.8	39.0	38.7
Mean	38.5	38.6	38.7	38.7	38.7	38.8	**38.7**
Hot							
Sheep 4	39.5	39.5	39.7	39.4	39.3	39.4	39.5
Sheep 5	39.5	39.2	39.3	39.2	39.0	39.3	39.3
Sheep 6	39.8	39.5	39.3	40.0	39.5	40.0	39.7
Mean	39.6	39.4	39.4	39.5	39.3	39.6	**39.5**
SEM							0.3
Significance Level						**	
RESPIRATION RATE (per minute)							
Mild							
Sheep 1	48	50	46	48	50	50	49
Sheep 2	42	42	42	42	46	44	43
Sheep 3	42	46	48	50	48	46	47
Mean	44	46	45	47	48	47	**46**
Hot							
Sheep 4	104	106	110	106	104	108	106
Sheep 5	116	108	108	108	106	108	109
Sheep 6	120	116	110	120	114	118	116
Mean	113	110	109	111	108	111	**110**
SEM							8
Significance Level						***	

7.3.2 CHEMICAL ANALYSIS OF THE FEEDS

Chemical analyses of the feeds used in the present study are given in Table 7.3.2.

Table 7.3.2 The chemical composition of the concentrates and hay.

Concentrate	0% urea	1% urea	2% urea
Dry matter (%)	88.1	88.6	88.2
Crude protein (%)	26.9	26.3	24.1
In vitro			
Dry matter digestibility (%)	74.7	75.9	75.2
Organic matter digestibility (%)	79.1	80.5	79.8
Digestible organic matter in the dry matter (%)	72.9	74.9	74.7
Estimated metabolisable energy (MJ/kgDM) [1/]	11.7	12.0	11.9
Cellulose (%)	8.7	7.9	7.7
Hemicellulose (%)	23.4	23.8	23.7
Lignin (%)	1.4	1.5	1.4
Ash (%)	5.9	4.6	3.9
Hay	period 1	period 2	period 3
Dry matter (%)	86.6	87.0	86.7
Crude protein (%)	8.9	7.3	8.9
In vitro			
Dry matter digestibility (%)	52.1	49.3	50.1
Organic matter digestibility (%)	54.3	51.3	52.4
Digestible organic matter in the dry matter (%)	49.9	47.5	48.4
Estimated metabolisable energy (MJ/kgDM) [1/]	8.0	7.6	7.7
Cellulose (%)	34.3	37.2	34.9
Hemicellulose (%)	30.1	33.2	32.3
Lignin (%)	4.5	4.5	4.9
Ash (%)	6.8	6.0	6.2

[1/] Estimated ME = 0.16DOMD (MAFF, 1975).

7.3.3 VOLUNTARY FOOD INTAKE

The terms 'temperature' and 'urea' will be used throughout this chapter to denote the two respectively temperature conditions and the three levels of urea addition to the concentrate.

The mean values of hay dry matter intake and water intake are presented in Table 7.3.3. These showed that high temperature conditions depressed hay DM intake ($p<0.10$). The 1% inclusion of urea had no significant effect on hay DM intake whereas 2% urea caused a significant ($p<0.05$) reduction.

Neither 'temperature' nor 'urea' had significant effects on concentrate DM intake ($p>0.10$). The 2% urea concentrate depressed total DM consumption ($p<0.05$) whereas 1% urea concentrate had no significant effect.

In contrast to hay DM intake, water intake (ml/kgDM eaten) was increased by high temperature conditions. Sheep in the high temperature conditions drank 30% more water than those held at mild ambient temperature.

The addition of 2% urea reduced water intake ($p<0.10$), however, this effect might have been caused by the reduced hay DM intake. There were no statistical significant interactions between 'temperature' and 'urea' although the 'apparent' interactions were evident in intakes of hay DM, total DM and water.

Table 7.3.3 Mean values for hay dry matter intake, concentrate dry matter intake, total dry matter intake (gDM/day) and water intake (ml/kgDM eaten) under mild and hot conditions.

	Mild	Hot	Significant Effect				
			Temperature	Urea	Period	Sheep	Temperature and Urea Interaction
Hay DM intake							
0% urea	584	588		a			
1% urea	569	416		ab			
2% urea	509	408		b			
	560	471	p<0.10	p<0.05	NS	NS	NS
Concentrate DM intake							
0% urea	302	302					
1% urea	302	303					
2% urea	302	292					
	302	299	NS	NS	NS	NS	NS
Total DM intake							
0% urea	886	890		a			
1% urea	871	719		ab			
2% urea	811	700		b			
	862	770	NS	p<0.05	NS	p<0.10	NS
Water intake							
0% urea	4226	6121					
1% urea	4428	5726					
2% urea	3365	5572					
	4006	5806	p<0.05	NS	NS	NS	NS

a, b (Urea) shows different letters are significant difference.

7.3.4 DIGESTIBILITY

The effects of 'urea' and 'temperature' on *in vivo* digestibilities of dry matter and crude protein are presented in Table 7.3.4. Although the results showed that there was no significant effect of 'temperature' or 'urea' on total DM digestibility, there was a suggestion that the addition of 1% urea had a favourable effect at both temperatures.

Neither 'temperature' nor 'urea' had a significant effect on crude protein digestibility ($p>0.10$).

Table 7.3.4 Mean values for *in vivo* digestibilities (%) of total DM and crude protein under mild and hot conditions.

	Mild	Hot	Significant Effect				
			Temperature	Urea	Period	Sheep	Temperature and Urea Interaction
DM digestibility							
0% urea	60.4	60.0					
1% urea	63.5	61.7					
2% urea	61.2	60.6					
	61.8	60.8	NS	NS	NS	NS	NS
Crude protein digestibility							
0% urea	66.8	67.5					
1% urea	68.7	70.6					
2% urea	68.1	67.6					
	67.8	68.6	NS	NS	NS	NS	NS

7.3.5 NITROGEN BALANCE

The mean values for nitrogen intake, faecal N loss, urinary N loss and N retention (by difference) are given in Table 7.3.5. The mean values for nitrogen intake at high and mild temperatures were similar. However, the 2% urea sheep had a lower value for nitrogen intake than the 0% urea sheep, due to their lower intake of hay.

Neither 'temperature' nor 'urea' had significant effects on faecal, urinary nitrogen losses or nitrogen retention.

Although there were no significant differences in urinary N loss between the sheep in the different treatment groups there was a tendency for the sheep receiving 2% urea at the high temperature to have higher values than those at the low temperature.

7.3.6 RUMEN FLUIDS

7.3.6.1 pH

The mean values for rumen pH at various times of sampling as affected by 'urea' and 'temperature' are presented in Table 7.3.6 and none of the differences was significant. There was however a tendency for lower pH values to be associated with sheep held at the higher temperature. The variations of rumen pH between 'temperature' and 'urea' at various times of measurements are illustrated in Figure 7.2.

Table 7.3.5 **Mean values for total nitrogen (N) intake, faecal N loss, urinary N loss, N retention and ratio of N retention/N intake under mild and hot conditions.**

	Mild	Hot	Significant Effect				
			Temperature	Urea	Period	Sheep	Temperature and Urea Interaction
Nitrogen Intake (gN/day)							
0% urea	20.6	20.6		a			
1% urea	20.3	18.6		ab			
2% urea	17.9	16.8		b			
	19.8	18.7	NS	p<0.05	p<0.05	NS	NS
Faecal N loss (mgN/gN intake)							
0% urea	332	325					
1% urea	312	294					
2% urea	319	324					
	321	314	NS	NS	NS	NS	NS
Urinary N loss (mgN/gN intake)							
0% urea	335	290					
1% urea	348	347					
2% urea	333	354					
	340	330	NS	NS	NS	NS	NS
Nitrogen Retention (mgN/gN intake)							
0% urea	333	386					
1% urea	339	359					
2% urea	348	322					
	339	356	NS	NS	NS	NS	NS

a, b as in Table 7.3.3.

Table 7.3.6 Mean values for rumen pH under mild and hot conditions.

	Mild	Hot	Significant Effect				
			Temperature	Urea	Period	Sheep	Temperature and Urea Interaction
Hour 0 (Before concentrate feeding)							
0% urea	6.47	6.28					
1% urea	6.33	6.28					
2% urea	6.53	6.42					
	6.43	6.34	NS	NS	NS	NS	NS
Hour 3							
0% urea	6.08	5.87					
1% urea	6.09	5.99					
2% urea	6.14	6.07					
	6.10	5.98	NS	NS	NS	NS	NS
Hour 5							
0% urea	6.21	5.98					
1% urea	6.10	6.12					
2% urea	6.18	6.10					
	6.16	6.07	NS	NS	$p<0.05$	NS	NS
Hour 7							
0% urea	6.24	6.05					
1% urea	6.17	6.16					
2% urea	6.32	6.20					
	6.23	6.14	NS	NS	$p<0.05$	$p<0.05$	NS
Hour 0-Hour 7 (means)							
0% urea	6.25	6.04					
1% urea	6.17	6.17					
2% urea	6.29	6.18					
	6.23	6.13	NS	NS	$p<0.10$	NS	NS

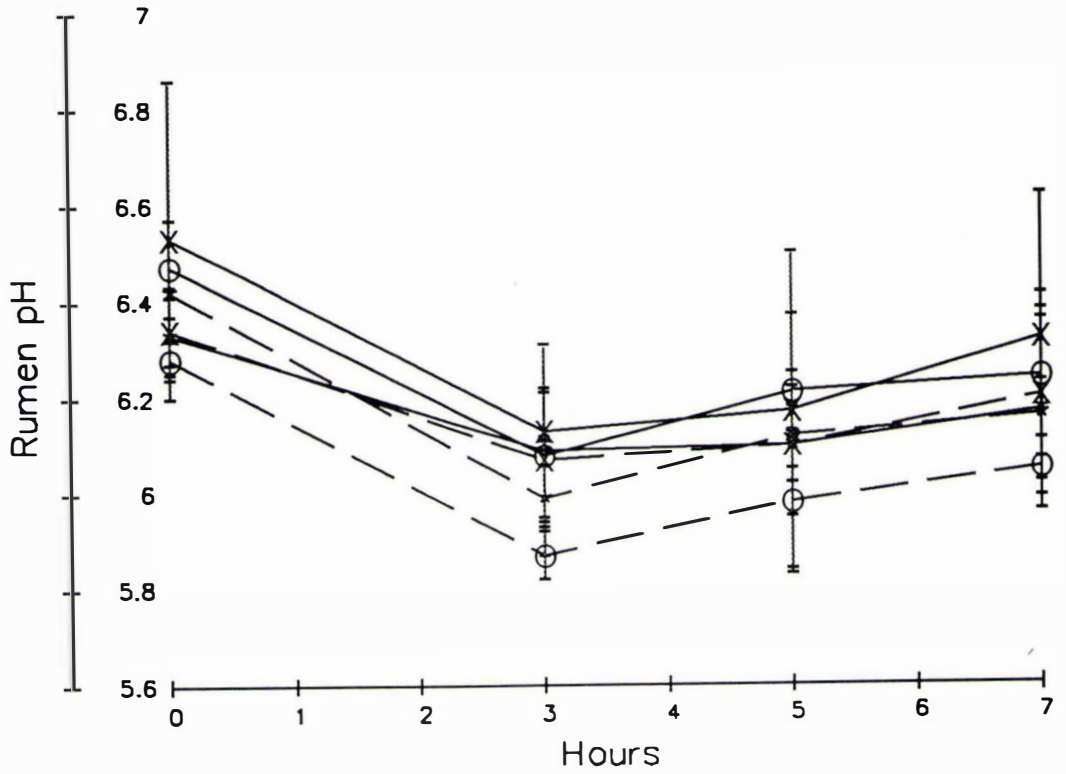

Figure 7.2 Mean rumen pH at various measuring times after concentrate feeding of sheep fed different concentrates under mild (solid lines) and hot (dashed lines) ambient temperatures [no urea shown (o), 1% urea shown (*), 2% urea shown (x)].

7.3.6.2 Ammonia Concentration

The values for ammonia concentration in the rumen liquor are presented in Table 7.3.7 and were similar at different temperatures and for different urea additions. However, surprisingly, the sheep fed 2% urea in concentrates tended to have the lowest values of ammonia concentration in the rumen and this is due to the association with lower N intake. The tendency of lower rumen ammonia concentration in sheep fed 2% concentrate than 0% and 1% concentrates would not be expected soon after feeding, however, the present study did not measure rumen ammonia concentration at 1 and 2 hours after feeding. The variations of rumen ammonia concentration between 'temperature' and 'urea' at various times of measurements are illustrated in Figure 7.3.

Table 7.3.7 **Mean values for ammonia concentration (mgNH3-N/litre) under mild and hot conditions.**

	Mild	Hot	Significant Effect				
			Temperature	Urea	Period	Sheep	Temperature and Urea Interaction
Hour 0 (Before concentrate feeding)							
0% urea	91.7	121.1					
1% urea	125.7	139.9					
2% urea	107.6	112.2					
	108.4	124.4	NS	NS	$p<0.05$	NS	NS
Hour 3							
0% urea	181.5	172.1					
1% urea	152.2	170.7					
2% urea	166.5	159.9					
	166.7	167.6	NS	NS	NS	NS	NS
Hour 5							
0% urea	158.4	147.1					
1% urea	111.9	125.4					
2% urea	104.7	140.0					
	127.5	137.5	NS	NS	NS	NS	NS
Hour 7							
0% urea	145.5	121.4					
1% urea	129.0	121.0					
2% urea	86.7	104.7					
	124.6	115.7	NS	NS	NS	NS	NS
Hour 0-Hour 7 (means)							
0% urea	158.5	140.4					
1% urea	129.7	139.2					
2% urea	116.4	129.2					
	137.2	136.3	NS	NS	NS	NS	NS

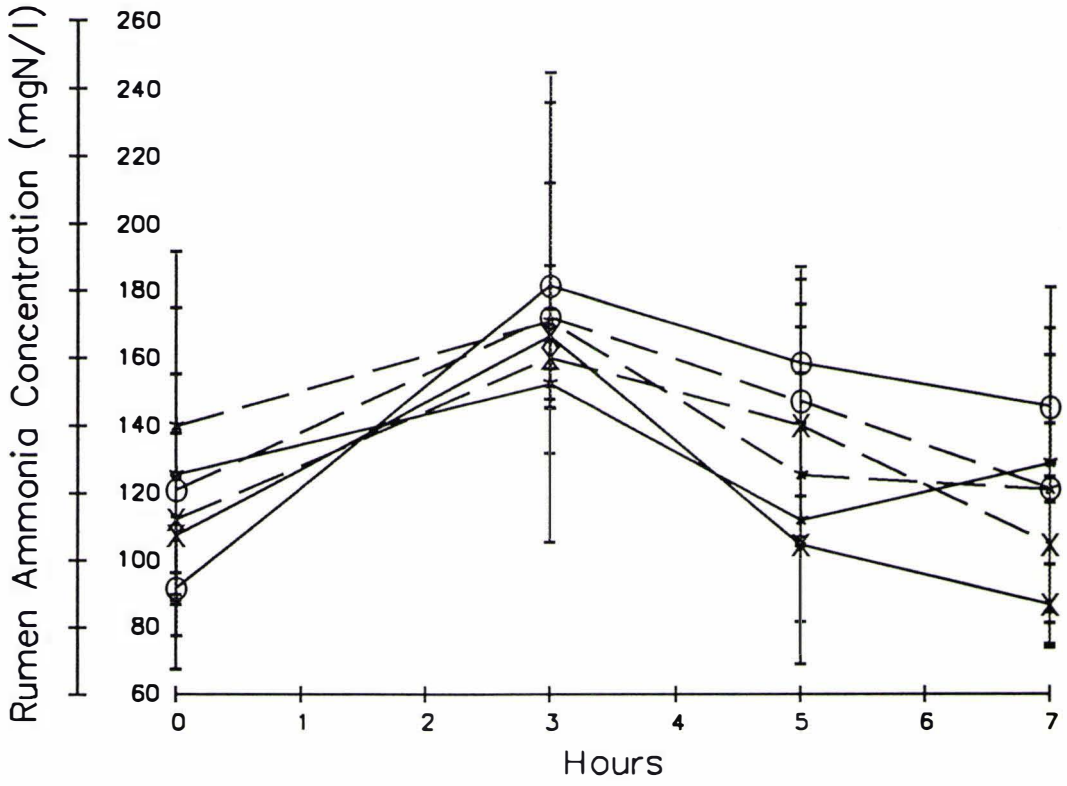

Figure 7.3 Mean rumen ammonia concentration (mgN/litre) at various measuring times after concentrate feeding of sheep fed different concentrates under mild (solid lines) and hot (dashed lines) ambient temperatures (o, *, x as in Figure 7.2).

7.3.6.3 Volatile Fatty Acids

Mean values for total volatile fatty acids (mM/l), and for the molar proportions of acetate, propionate and N-butyrate are shown in Tables 7.3.8, 7.3.9, 7.3.10 and 7.3.11 respectively. These showed that the total VFA concentrations averaged over the day were similar ($p>0.10$) for the different 'temperature' and 'urea'. However, the total VFA concentration was significantly reduced by high temperature at 3, 5 and 7 hours after feeding. The total VFA concentration was also significantly reduced with increasing urea addition (especially at the high temperature) at 3 and 5 hours after feeding.

The molar proportions of acetic acids were also similar for both temperatures and different urea additions at h 0, 3 and 7. For the 5 h sample the addition of urea caused reductions in the molar proportion of acetic acid ($p<0.05$). There was also a small interaction at h 7 between temperature and urea addition ($p<0.10$). Total volatile fatty acids tended to be lower when urea was added and in association with lower hay intake. Hot temperature also tended to reduce total concentration of volatile fatty acids.

There were effects of period, sheep and interactions between temperature and urea addition on the molar proportion of propionic acid present. This suggested that there was variation across period and between sheep.

Addition of urea increased the molar proportion of propionic acid significantly at h 5 after feeding concentrate ($p<0.01$).

No significant effects of either temperature or urea addition to concentrate on molar proportion of N-butyrate were found ($p>0.10$).

Table 7.3.8 **Mean values for total volatile fatty acids (mM/l) under mild and hot conditions.**

	Mild	Hot	Significant Effect				
			Temperature	Urea	Period	Sheep	Temperature and Urea Interaction
Hour 0 (Before concentrate feeding)							
0% urea	71.9	80.0					
1% urea	86.0	62.2					
2% urea	73.6	73.6					
	77.2	71.9	NS	NS	NS	NS	NS
Hour 3							
0% urea	100.4	95.8		a			
1% urea	94.7	71.0		ab			
2% urea	89.6	74.8		b			
	94.9	80.5	p<0.05	p<0.10	NS	p<0.10	NS
Hour 5							
0% urea	97.8	90.8		a			
1% urea	88.3	71.1		ab			
2% urea	81.3	72.6		b			
	89.2	78.2	p<0.10	p<0.05	NS	p<0.10	NS
Hour 7							
0% urea	91.5	79.1					
1% urea	85.6	71.6					
2% urea	82.9	75.2					
	86.7	75.3	p<0.10	NS	NS	NS	NS
Hour 0-Hour 7							
0% urea	90.4	86.4					
1% urea	88.7	69.0					
2% urea	81.9	74.1					
	87.0	76.5	p<0.10	NS	NS	NS	NS

a, b as in Table 7.3.3.

Table 7.3.9 **Mean values for acetic acid (molar proportion of total VFA) under mild and hot conditions.**

	Mild	Hot	Significant Effect				
			Temperature	Urea	Period	Sheep	Temperature and Urea Interaction
Hour 0 (Before concentrate feeding)							
0% urea	69.3	68.6					
1% urea	69.1	66.6					
2% urea	68.1	69.4					
	68.8	68.2	NS	NS	NS	NS	NS
Hour 3							
0% urea	67.3	65.0					
1% urea	68.1	63.8					
2% urea	63.9	67.1					
	66.5	65.3	NS	NS	NS	NS	p<0.10
Hour 5							
0% urea	68.5	67.4		a			
1% urea	66.3	64.3		b			
2% urea	62.7	66.2		b			
	65.8	66.0	NS	p<0.10	NS	NS	NS
Hour 7							
0% urea	67.1	68.6					
1% urea	69.7	65.6					
2% urea	63.4	68.4					
	66.7	67.5	NS	NS	NS	NS	p<0.05
Hour 0-Hour 7 (means)							
0% urea	68.1	67.4					
1% urea	68.3	65.1					
2% urea	64.5	67.8					
	67.0	66.8	NS	NS	NS	NS	p<0.10

a, b as in Table 7.3.3.

Table 7.3.10 **Mean values for propionic acid (molar proportion of total VFA) under mild and hot conditions.**

	Mild	Hot	Significant Effect				
			Temperature	Urea	Period	Sheep	Temperature and Urea Interaction
Hour 0 (Before concentrate feeding)							
0% urea	15.8	16.8					
1% urea	16.0	17.6					
2% urea	17.5	15.6					
	16.4	16.6	NS	NS	p<0.05	NS	NS
Hour 3							
0% urea	18.2	19.8					
1% urea	18.5	21.4					
2% urea	21.9	17.6					
	19.5	19.6	NS	NS	NS	p<0.10	p<0.05
Hour 5							
0% urea	17.7	19.0		b			
1% urea	18.8	21.0		a			
2% urea	21.2	18.2		a			
	19.2	19.4	NS	p<0.01	NS	p<0.01	p<0.01
Hour 7							
0% urea	17.9	18.3					
1% urea	17.0	19.9					
2% urea	20.8	17.0					
	18.6	18.4	NS	NS	p<0.10	p<0.05	p<0.01
Hour 0-Hour 7 (means)							
0% urea	17.7	18.5					
1% urea	17.6	20.0					
2% urea	20.3	17.1					
	18.4	18.5	NS	NS	p<0.05	p<0.01	p<0.01

a, b as in Table 7.3.3.

Table 7.3.11 Mean values for N-butyric acid (molar proportion of total VFA) under mild and hot conditions.

	Mild	Hot	Significant Effect				
			Temperature	Urea	Period	Sheep	Temperature and Urea Interaction
Hour 0 (Before concentrate feeding)							
0% urea	11.2	10.8					
1% urea	11.4	12.1					
2% urea	10.8	11.9					
	11.1	11.6	NS	NS	NS	NS	NS
Hour 3							
0% urea	11.4	11.9					
1% urea	10.8	12.1					
2% urea	11.2	12.4					
	11.1	12.1	NS	NS	$p<0.10$	NS	NS
Hour 5							
0% urea	10.9	11.0					
1% urea	11.8	11.8					
2% urea	12.8	12.7					
	11.8	11.8	NS	NS	NS	NS	NS
Hour 7							
0% urea	12.1	10.6					
1% urea	10.5	11.7					
2% urea	11.6	11.8					
	11.4	11.3	NS	NS	NS	NS	$p<0.10$
Hour 0-Hour 7							
0% urea	11.4	11.1					
1% urea	11.1	11.9					
2% urea	11.6	12.2					
	11.4	11.7	NS	NS	NS	NS	NS

7.3.7 RUMEN DEGRADABILITY OF DRY MATTER AND PROTEIN

The data from the 12, 24 (concentrate and hay) and 48 h (hay) incubations were analysed by analysis of variance in the Latin Square to determine effects of 'urea' and 'temperature' on the degradation rates of feed samples. This was because the equation of Orskov and McDonald (1979) was not appropriate due to the small number of sample times.

The mean values for the degradability of crude protein in the concentrates after 12 and 24 h incubation and hay after 12, 24 and 48 h incubation are presented in Table 7.3.12. These showed that the 1% and especially the 2% urea concentrates had higher values for protein degradability after 12 and 24 h incubation than the 0% urea concentrates. The higher degradabilities of crude protein can be attributed to the high degradability of urea.

The mean values for degradability of crude protein in hay after 12, 24 and 48 h incubation were similar for the sheep fed the three concentrates. However, for both the 12 and 24 h incubations, the sheep held in hot conditions had lower values for degradability of hay crude protein ($p<0.05$ and 0.10 at 12 and 24 h incubation respectively) but not for 48 h incubation ($p>0.10$).

The mean values for degradability of dry matter in the concentrates after both 12 and 24 h incubations and hay after 12, 24 and 48 h incubations are presented in Table 7.3.13. Adding 1 or 2% urea to the concentrates did not significantly alter the degradability of the dry matter in the concentrates or the hay. However, the initial rate of degradability (12 h) of the concentrates tended to be higher due to urea being degraded rapidly, and of hay lower, for the rations containing urea.

Table 7.3.12 Mean values for protein degradability (%) in concentrates and hay under mild and hot conditions.

	Mild	Hot	Significant Effect				
			Temperature	Urea	Period	Sheep	Temperature and Urea Interaction
Concentrate							
12 h							
0% urea	32.0	30.6		c			
1% urea	39.0	42.3		b			
2% urea	55.7	47.9		a			
	40.6	40.3	NS	p<0.01	p<0.01	NS	NS
24 h							
0% urea	52.0	38.8		c			
1% urea	50.1	47.3		b			
2% urea	59.9	61.2		a			
	53.3	49.1	NS	p<0.10	p<0.05	NS	NS
Hay							
12 h							
0% urea	37.0	28.7					
1% urea	37.0	25.8					
2% urea	34.0	36.4					
	36.3	30.3	p<0.05	NS	p<0.01	NS	NS
24 h							
0% urea	53.1	44.0					
1% urea	49.3	41.1					
2% urea	47.0	49.4					
	50.1	44.8	p<0.10	NS	p<0.10	NS	NS
48 h							
0% urea	63.1	56.3					
1% urea	56.3	53.4					
2% urea	58.2	58.0					
	59.3	55.9	NS	NS	p<0.05	p<0.05	NS

a, b, c as in Table 7.3.3.

Table 7.3.13 Mean values for dry matter degradability (%) in concentrates and hay under mild and hot conditions.

	Mild	Hot	Significant Effect				
			Temperature	Urea	Period	Sheep	Temperature and Urea Interaction
Concentrate							
12 h							
0% urea	42.4	42.3					
1% urea	45.5	47.6					
2% urea	49.0	45.2					
	45.2	45.1	NS	NS	$p<0.05$	NS	NS
24 h							
0% urea	58.2	50.9					
1% urea	58.1	54.1					
2% urea	54.5	57.2					
	57.3	54.0	NS	NS	$p<0.10$	NS	NS
Hay							
12 h							
0% urea	27.2	26.0					
1% urea	25.9	21.0					
2% urea	25.9	23.9					
	26.4	23.6	NS	NS	NS	NS	NS
24 h							
0% urea	37.9	36.5					
1% urea	37.3	35.6					
2% urea	35.6	37.4					
	37.1	36.5	NS	NS	NS	NS	NS
48 h							
0% urea	51.2	51.2					
1% urea	45.9	49.5					
2% urea	49.4	48.2					
	48.8	49.6	NS	NS	NS	NS	NS

7.3.8 CALCULATED SUPPLY OF NUTRIENTS

Mean values for intakes of total ME and RDP, and the ratio of RDP/ME under mild and hot condition are shown in Table 7.3.14. Neither temperature nor urea had a significant effect on the supply of RDP. Temperature had no effect on ME intake but 2% urea had a marked effect ($p<0.05$) on ME intake due to the reduction in hay DM intake. The ratio of RDP/ME is considerably higher than that recommended by ARC (1984) i.e. 8.1 gRDP/MJME. Temperature had no effect on the ratio of RDP/ME but addition of 2% urea significantly increased RDP/ME ($p<0.01$).

Table 7.3.14 Mean values for total ME intake (MJ/day), RDP supply (g/day) and ratio of RDP/ME (gRDP/MJME) under mild and hot conditions.

	Mild	Hot	Significant Effect				
			Temperature	Urea	Period	Sheep	Temperature and Urea Interaction
Total ME intake[1/]							
0% urea	8.1	8.1		a			
1% urea	8.1	6.9		ab			
2% urea	7.6	6.7		b			
	7.9	7.2	NS	p<0.05	NS	p<0.10	NS
RDP supply[2/]							
0% urea	66.0	66.6					
1% urea	65.5	58.2					
2% urea	67.7	62.6					
	66.2	62.5	NS	NS	p<0.05	p<0.10	NS
RDP/ME							
0% urea	8.2	8.2		b			
1% urea	8.2	8.5		b			
2% urea	9.0	9.4		a			
	8.4	8.7	NS	p<0.01	NS	NS	NS

1/ from values reported in Table 7.3.2.
2/ estimated from values for 24 h degradability of protein in the concentrates and 48 h degradability of protein in the hay (averaged across both temperature; Table 7.3.12)
a, b as in Table 7.3.3.

7.4 DISCUSSION

The present study was intended to examine the effects of feeding concentrates of the same crude protein percentage but containing protein with different degradabilities (by inclusion of urea) to sheep fed on low quality hay under 'mild' and 'hot' environmental conditions on voluntary feed intake, *in vivo* digestibility of rations, nitrogen retention, aspects of digestion including rumen pH, rumen ammonia concentration and volatile fatty acid production, and rate and extent of feed degradation.

7.4.1 EFFECT ON VOLUNTARY OF FOOD INTAKE

7.4.1.1 Effect on DM Intakes of Hay, Concentrate and Total Feed

Adding 2% urea to the concentrate reduced hay DM intake while 1% urea had no significant effect on hay DM intake although there was a tendency for the hay DM intake to be reduced. In contrast to the present study, supplementation of urea to low quality feed such as straw increased rumen ammonia concentration, increased digestibility of straw and thus increased straw DM intake in several previous studies (Krebs and Leng, 1984; Boniface *et al.*, 1986; Perdok *et al.*, 1988). In these trials involving the infusion of urea into the rumen, concentration of ammonia in the rumen increased for only 1 or 2 hours after once or twice daily infusions (Falvey, 1982). Preston and Leng (1987) cited the data from Leng (personal observation) where the same quantity of urea (10 g urea in 24 hours) was given in 1, 2, 4 and 10 portions or was infused continuously to sheep fed wheat straw. Straw intake was increased linearly as the frequency of urea feeding increased and was highest with 10 times feeding and continuous infusion.

It is possible that the lack of any increases in hay DM intake in the present study was due to the infrequent feeding of urea concentrates. This would have caused a brief increase in rumen ammonia concentration, with only a small proportion of extra

nitrogen being taken up by the rumen microorganisms and the rest was absorbed through rumen wall. This suggestion is supported by the tendency for higher urinary N losses in sheep receiving urea concentrate. Because of these events, the hay may be digested slowly (hay DM degradabilities slightly lower in sheep fed 1 and 2% urea than 0% urea concentrates; Table 7.3.13) and thus cause limited hay DM intake.

From a practical point of view, if urea has to be added to the concentrate, the readily fermentable sugar e.g. molasses should also be included. In addition, this concentrate should be given quite frequently to the animals. The use of multinutrient blocks containing urea, molasses and bypass protein, which can be offered free access, would be more appropriate since they may reduce the labour cost of frequent feeding.

Once the supplies of fermentable N and sugar are assured, the availability of amino acids in the intestines need to be further considered. For many of the feed basal diets that will be used in tropical countries, the value of bypass protein lies in its effects on increasing efficiency of use of absorbed nutrients and on increasing voluntary intake (Preston and Leng, 1987). Bypass proteins, such as cotton seed meal or fish meal, can also be included in the multinutrient blocks together with essential minerals, vitamins and possibly antibiotics.

Neither temperature nor urea had marked effects on concentrate DM intake in the present study as expected. However, the higher temperature caused reductions in hay DM intake. The total DM intake followed the same trend as hay DM intake. Total DM intake tended to be higher at the mild temperature compared to the hot temperature. Sheep receiving 2% urea concentrate ate less total DM than those receiving 0% urea concentrate. This reflected the lower intake of hay DM by the 2% urea concentrate group than the 0% urea group.

At high temperatures the animal will attempt to reduce heat production by reducing food intake in order to maintain normal body temperature (Young, 1987). The decrease in food intake at high temperature can be explained as a result of the need to reduce energy intake in order to reduce heat production (Weston, 1982; Young, 1986, 1987). During exposure to heat, metabolism is reduced and this was found to be associated with a reduction in thyroid secretion and an increase in gut fill (Fuquay, 1981; Christopherson and Kennedy, 1983; Christopherson, 1985; Lu, 1989).

In the present study, despite similar *in vivo* digestibility, an increase in food intake of sheep held at the mild temperature compared to at the hot temperature could be attributed to an increase in rumen volume, rate of passage of digesta or digesta turnover, and to the increased energy demand but a decrease in retention time (Baile and Forbes, 1974; Kennedy *et al.*, 1976; Westra and Christopherson, 1976; Weston, 1982; Kennedy *et al.*, 1986; Young, 1986, 1987). Warren *et al.* (1974) also reported that mean retention time in the digestive tract of steers given forage diets was increased from 36.6 to 43.2 h and probably an increase in digestibility of the feed when the temperature was increased from 18°C to 32°C.

7.4.1.2 Effect on Water Intake

Inclusion of urea in the concentrate had no effect on water intake (expressed as ml/kgDM intake) in the present study. In contrast, water intake was increased by the high temperature. Many experiments have shown increases in water intake with increasing ambient temperature (Blaxter *et al*, 1959; Moody *et al.*, 1967). Farm animals are homeothermic animals and they attempt to maintain a constant deep body temperature. When exposed to warm conditions, they usually attempt to increase their rate of evaporative heat losses, with consequent increases in water requirements at hot temperature (McDowell *et al.*, 1969; Bhattacharya and Uwayjan, 1975).

Rumen metabolism has been reported to be unaffected by increases in water intake (More *et al.*, 1983). More *et al.* (1983) recorded no significant differences in hay DM digestibility (%), faecal and urinary N losses (mg/gN intake), and N retention (mg/gN intake) between sheep consumed 3.2 or 5.4 ml/kgDM intake daily although urinary N losses tended to be higher in sheep consumed more water.

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7.4.2 EFFECT ON *IN VIVO* DM DIGESTIBILITY OF TOTAL DIET

In the present study, neither digestibilities of DM nor crude protein were affected by 'urea' or 'temperature'. Orskov *et al.* (1972) fed early weaned lambs with concentrates containing different levels of urea (from 0 to 2.2 %) and observed that there were no significant effects on digestibility of DM and OM but the apparent digestibility of crude protein increased with urea supplementation. In the same report (Orskov *et al.*, 1972), a second experiment found increases in DM digestibility by supplementation but the DM digestibility did not change significantly as the level of urea supplementation was increased. In their experiments, the % crude protein of the diet DM range from 9.0 (no urea) to 16.4, and the significant effect on DM digestibility was observed only when the higher CP concentration (with urea) in the diet was compared to the control (no urea). When comparisons were made between the urea supplementation (high CP concentration) the difference was not statistically significant. The interpretation of their results was probably confounded by the percentage of CP and urea addition.

The concentration of crude protein in the present study ranged from 14.2 to 15.9 which were in the high range of those diets used by Orskov *et al.* (1972). The observed similar DM digestibility between treatment was in agreement with Orskov *et al.* (1972) at the same range of %CP in the diets. It could be suggested that the total N rather than the high degradability of protein (by inclusion of urea) was the important factor to determine the ration digestibility.

Early reports published showed a positive relationship between environmental temperature and energy digestibility in sheep (Graham *et al.*, 1959) and in steers (Blaxter and Wainman, 1961). The effects of temperature on digestibility were not large. Later studies (Christopherson, 1976; Westra and Christopherson, 1976; Kennedy *et al.*, 1976; Kennedy and Milligan, 1978; Warren *et al.*, 1974; Colditz and Kellaway, 1972; Nicholson *et al.*, 1980) have confirmed that there is indeed an influence of environmental temperature on digestibility in sheep and cattle. However, there have also been several conflicting reports and some of these might be attributed to a confounding of temperature treatments with variations in feed intake and the possible selective refusal of some diet components (Bhattacharya and Hussain, 1974; Guerrini, 1981) all of which can introduce variability into digestion experiments.

However, those experiments quoted often involved comparison between mild (approximately 20°C) and cold (0°C or below) temperatures and animals were fed mainly on roughage diets.

The present study did not observe a difference in digestibility either of DM or crude protein in sheep between the temperatures of 13-18°C and 29-32°C.

In reviewing 10 experiments (6 with sheep and 4 with cattle), Young and Degen (1981) reported positive relationship between digestibility and temperature. Eight of the ten experiments reviewed compared 0°C or below and mild (approximately 20°C). However, two experiments with cattle compared mild (20°C) and hot (33 and 40°C) and found increases in digestibility with increasing temperature (All data reviewed were for roughage-based rations).

A possible reason that a difference in diet digestibility was not observed in the present study between different temperatures may be that temperature has less effect on the digestibility of concentrates than of roughage. The digestibility of forage diets which tend to be fermented slowly appears to be more susceptible to influence by temperature induced changes in motility and the rate of passage of digesta (Christopherson and Kennedy, 1983). Young and Degen (1981) observed that there was no effect of ambient temperature (1st experiment 20°C versus 30°C, 2nd experiment 0°C versus 30°C) on digestibility when shorn wethers were given a pelleted barley-alfalfa diet. Kennedy *et al.* (1982) established that temperature had no influence on digestibility of a rapidly fermented, all-concentrate (barley-canola meal) diet in wethers. Similar results have been reported for a milk replacer diet in young calves (William and Innes, 1982) and for an all-concentrate diet in lambs (McBride, 1982 quoted by Christopherson and Kennedy, 1983). Bhattacharya and Uwayjan (1975) also did not observe differences in digestibilities of DM, CP and energy in sheep fed 25:75, 50:50 and 75:25 hay to concentrate and held at either 21°C or 33°C.

7.4.3 EFFECT ON NITROGEN BALANCE

Neither temperature nor urea had significant effects on losses of nitrogen in faeces and urine, and on nitrogen retention in the present study. Unexpectedly, the inclusion of urea had a negative effect on nitrogen intake due to reduced hay DM intake. As the losses of nitrogen (gN/day) in faeces and urine, and retention of nitrogen all tended to be related to nitrogen intake, the results were therefore expressed as mgN/gN intake.

Although there were no statistical significant difference in urinary N loss between the two temperatures, the urinary N loss tended to be higher at high temperature with 2% urea inclusion (354 and 333 mgN/gN intake). This supported the expectation that the brief increase in degraded N in the rumen was absorbed through the rumen wall with only a small proportion being incorporated into microbial protein (See Section 7.4.1.1).

In the present study, approximately 33% of N intake was excreted in urine, approximately 32% in faeces, and approximately 35% retained in the body of the sheep held at two temperature conditions and between concentrate supplementation. It is possible that the intake of N in the present study did not differ significantly between the two temperatures. Similar observations to the present study (Colditz and Kellaway, 1972) have shown that when Friesian, Brahman x Friesian or Brahman heifers were held at 17°C or 38°C, N excreted in faeces and urine, and N retained in the body did not differ significantly between the two temperatures.

7.4.4 EFFECT ON RUMEN pH

Neither temperature nor urea had any marked effect on rumen pH measured in the present study. However, a trend towards higher pH with 2% urea could be attributed to the increased concentrate/hay ratio.

In the present study, although the effect of temperature on rumen pH was not significant, there was a tendency for lower pH values to be associated with sheep held at the higher temperature. This may have been caused by the decrease hay DM intake at the higher temperature and the consequent higher concentrate/hay ratio.

7.4.5 EFFECT ON RUMEN AMMONIA CONCENTRATION

In the present study, neither temperature nor urea had marked effects on rumen ammonia concentration. The lack of significant effect of urea on rumen ammonia concentration in the present study may have been due to the fact that ammonia concentration was not measured until 3 hour after feeding. During this time, rumen ammonia concentration, particularly in sheep fed 1 or 2% urea, may rise sharply and then decline to the level that was observed at 3 hours after feeding. Falvey (1982) observed that rumen ammonia concentration rose sharply to the peak (320 mgNH_3-N/litre of rumen fluid) soon (less than 1 hour) after urea was fed then declined to normal (30 mgNH_3-N/litre) for the rest of the day after 3-4 hours after feeding.

Preliminary observations (Figure 7.4) on rumen pH suggested that rumen pH decreased from 6.5 at 0 h (before feeding) to 6.35, 6.20 and 6.00 at 1, 2 and 3 hours after feeding respectively, and the observations published by Leng and Nolan (1984) suggested that rumen ammonia concentration is normally positively associated with rumen pH. If this is the case, the concentration of rumen ammonia would probably have been higher at 1 or 2 hours than at 3 hours after feeding.

The lower concentration of rumen ammonia observed at 3 hours after feeding on the 1 and 2% urea treatments than on no urea treatment could be attributed to, firstly, very rapid degradation of urea to yield ammonia on the two urea treatments, with the ammonia taken up by microbes or lost through the rumen wall very rapidly. Secondly, the dietary protein from the 0% urea concentrate was slowly degraded. In the first case, part of ammonia in the rumen was incorporated into microbial N and the major part may have been absorbed through the rumen wall since high ammonia concentration associated with high rumen pH will lead to rapid absorption of ammonia from the rumen (Hogan, 1961). Leng and Nolan (1984) also observed approximately 10 times the rate of absorption at pH 7.0 compared to the rate at pH 6.0. In the second case, the slowly degraded dietary protein from the 0% urea concentrate should maintain higher rumen ammonia over a longer period compared to the urea concentrate. This was confirmed by the slightly higher rumen ammonia concentration measured at 3, 5 and 7 hours after feeding on the 0% urea concentrate compared to the urea concentrates.

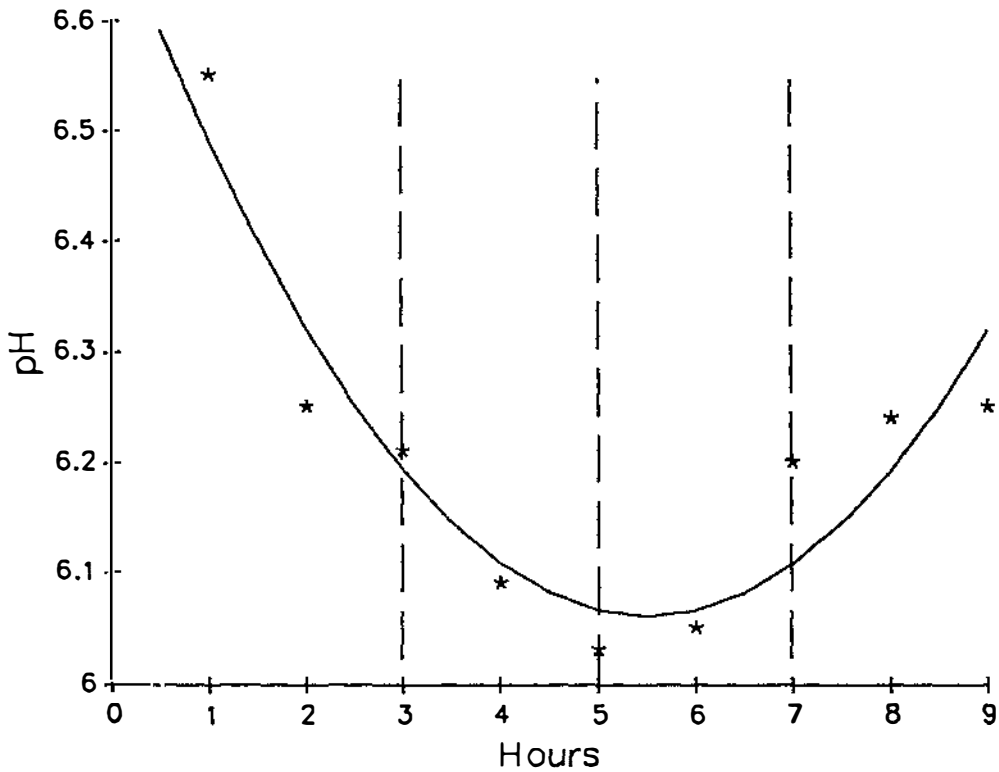

Figure 7.4 Preliminary measurement of rumen pH of sheep fed an equal mixture of concentrates (300 gDM/day) and *ad libitum* hay, at various measuring times after concentrate feeding.
Mean of measurement made from 4 sheep shown (*).

$y = 6.70 - 0.23x + 0.02x^2$ (where x = pH)

The minimum rumen ammonia concentration for maximum efficiency of microbial protein synthesis has been estimated *in vitro* to be 50-80 mg ammonia N/litre of rumen fluid (Satter and Slyter, 1974) and *in vivo* to vary with the diet but to range from 20 to 80 mg ammonia N/litre (Pisulewski *et al.*, 1981). However, recent studies have clearly indicated that the minimum level of ruminal fluid ammonia for optimum intake of low N, low digestibility forage by cattle is about 200 mgNH_3-N/litre, even though the digestibility of the forage in nylon bags was optimised below 100 mg ammonia N/litre (Krebs and Leng, 1984; Boniface *et al.*, 1986; Perdok *et al.*, 1988). As much as 235 mg ammonia N/litre has been reported to be required for maximum rate of fermentation (Mehrez *et al.*, 1977).

The concentration of rumen ammonia measured in the present study ranged from 90 to 180 mg N/litre which should optimise the digestion of hay. However, the higher rumen ammonia concentration throughout the measurement period on the 0% urea should have resulted in higher digestion of fibre than with the 1 and 2% urea concentrates. This was confirmed when DM degradability in the nylon bags was carried out and will be discussed later in the feed degradation section (7.4.7).

7.4.6 EFFECT ON VOLATILE FATTY ACID PRODUCTION

In the present study, adding 2% urea to the concentrate significantly reduced the concentration of total volatile fatty acids particularly during the early hours after feeding (3 and 5 h) but not on average over the day.

It was probable that urea *per se* had no direct effect on VFA production but the level of intake did affect the production of VFA. Total DM intake and VFA production were associated with each other in the present study. With the exception of measurements made at hour 0, the production of VFA was positively related to total DM intake.

In the present study, hot temperature conditions caused a reduction in total VFA concentration at 3, 5 and 7 hours after feeding and VFA concentration averaged over the day. This was similar to the findings of Kelly *et al.* (1967) who reported that total VFA concentration declined significantly from 147 mM/litre to 66 mM/litre as the temperature increased from 18.2 to 37.7°C. It is clear that hot temperature reduced food intake and consequently caused a reduction in VFA production.

Neither temperature nor urea had any effect on average molar proportion (over the day) of acetic, propionic and N-butyric acids in the present study. However, at 5 hours after feeding molar proportion of acetic acid was decreased by urea but the molar proportion of propionic acid was increased by urea. The low concentration of ammonia observed at 5 hour after feeding with 1 and 2% urea may contribute to a reduction in fibre digestion in the rumen and thus a reduction in molar proportion of acetic acids relative to propionic acids. It was likely that the results obtained were caused little by the direct effect of urea itself since the molar proportions of acetic and propionic acids were likely to be dominantly associated with the ratio (concentrate:hay).

Published reports have shown similar molar proportions of acetic acid, propionic acid and butyric acid when non-lactating cows (Kelly *et al.*, 1967) or lactating cows (Moody *et al.*, 1967) were exposed to warm (18.2 and 15-24°C respectively) and hot (37.7 and 32.2°C respectively) temperatures. The lack of any marked effect of temperature on molar proportions of acetic and propionic acids in the present study was similar to the published works quoted.

7.4.7 EFFECT ON FEED DEGRADATION

In the present study, increases in urea in the concentrate resulted in increases in protein degradability of concentrates as expected. Increases in protein degradability was undoubtedly due to the high degradability of urea.

Urea had no effect on protein degradability of hay while mild temperature conditions increased protein degradability of hay significantly at 12 and 24 h and increased it slightly at 48 h after incubation in the present study. The higher degradability of protein in hay at mild than hot temperature was unexpected since increased rate of digesta passage in association with increased DM intake (Warren *et al.*, 1974; Kennedy and Milligan, 1978; Tamminga, 1979; Evans, 1981) at mild temperatures (as occurred in the present study) would be expected to result in the depression of degradability of protein in the rumen. In the trial by Warren *et al.* (1974) a decreased passage rate when cattle were exposed to 18°C compared to 32°C was also recorded.

A possible reason for lower protein degradability of hay in hot than in mild condition is that hot temperature significantly reduced hay DM intake and consequently increased concentrate:hay ratio. Reduced hay cellulose disappearance from nylon bags incubated in the rumen of sheep, possibly due to changes in microorganisms population i.e. a reduction in cellulolytic microorganisms, has been reported when concentrate was supplemented to grass hay (Lamb and Eadie, 1979). Higher concentrate:hay ratio in hot than in mild condition may reduced hay cellulose digestion to a greater extent. As a result, a lower protein degradability of hay in hot than in mild condition is probably due to lower digestion of hay.

Neither temperature nor urea had marked effects on DM degradability of concentrate and hay in the present study. The tendency towards the higher DM degradability of concentrate at 24 h and of hay at 12 h at lower temperatures was unexpected since increased rate of digesta passage in association with low temperatures has been reported (Westra and Christopherson, 1976; Christopherson and Kennedy, 1983) and this should result in the depression of degradability of DM in the rumen.

A possible reason for a slightly lower DM degradability of hay at hot than at mild temperature can be explained as in the case of lower protein degradability of hay previously mentioned.

The tendency towards the higher hay DM degradability with the 0% urea concentrate compared to the urea concentrates could be explained by the higher rumen ammonia concentration, averaged over 24 hours, with the 0% urea diet.

7.5 CONCLUSIONS

1. There were no major favourable effects of adding urea to the concentrate in the present study. This was probably because the concentrates used were balanced for CP concentration with varying only protein degradability by inclusion of urea. The adverse effect of adding urea on hay DM intake may be due to the fact that urea was degraded to ammonia very rapidly in the rumen and thus had little advantage to microbes to produce microbial protein. If this is the case, frequent feeding of concentrate containing urea would have considerable major advantage. Another promising method is to supplement low quality roughage based diet by multi-nutrient block containing urea, molasses, bypass protein and minerals which animals may be access at all time. This would give continuous distribution of ammonia to the rumen.

2. Similar to many published reports, the present study has shown negative effects of temperature on DM intake, concentration of total VFA, degradability of protein but positive effects on respiration rate, and water intake. It can be concluded that in the present study the temperature had more marked effects on the parameters measured than the rations.

3. In view of practical implication, under tropical farming conditions where temperatures play a major role in animal production responses due to limited intakes of nutrients imposed by heat stress, supplementation of adequate fermentable energy and protein would be necessary to stimulate microbial growth in the rumen. The use of multi-nutrient blocks which give animal free to access, would be more appropriate since they may reduce the labour cost of frequent feeding. This field of research is required to obtain appropriate feeding practice.

CHAPTER 8

EFFECT OF HIGH PROTEIN MEAL SUPPLEMENTATION ON PERFORMANCE OF GRAZING DAIRY COWS IN WINTER

8.1 INTRODUCTION AND OBJECTIVES

Although the New Zealand dairy industry is based on a seasonal calving pattern with more than 90% of all herds calving in late winter/early spring, the remaining 10% are required to produce milk for liquid consumption during the autumn/winter period. The level of milk production obtained from autumn calvers has been reported to be different from that from spring calvers (Wilson *et al.*, 1985; Baldwin and Holmes, 1989; Hislop, 1991). For example, in a survey Baldwin and Holmes (1989) reported a similar whole lactation milk fat production per cow from autumn and spring calvers. The autumn calving herds were however fed 75% more hay and silage, and fed more concentrates than the spring calving herds and cows also had longer lactations. Hislop (1991) reported 184 kg milk fat per cow from autumn calvers and approximately 165 kg milk fat per cow from spring calvers. In contrast, Wilson (1989) stated that the milk production from autumn calvers was lower than from spring calvers.

The differences in the results observed may be due to the differences in nutritive value between autumn and spring pasture, and to the influence of fungi in pasture i.e. ill-thrift in sheep (Scott *et al.*, 1976). Reid (1986) recorded a faster growth rate (approximately double) of bull beef cattle on spring than on autumn pasture at the same pasture allowance (ranging from 2 to 8 kgDM/100 kgLW daily) despite similar digestibility but higher N concentration in autumn pasture. As a result, if differences between autumn and spring pasture in nutritive value resulted from differences in absorption of glucogenic amino acids in the small intestine, then much of extra N must have been lost from the rumen (MacRae *et al.*, 1985). Reid (1986) also noted that predicted pasture allowances required for maintenance or for maximum growth rates of beef cattle in autumn/winter were double those required in spring.

It is also possible that the nutritive value of autumn/winter pasture may be lower than that of spring pasture (MacRae *et al.*,1985), in spite of its high protein concentration (approximately 25%) and high digestibility (approximately 75%) (Bryant and Trigg, 1982).

In United Kingdom, earlier work by Corbett *et al.*(1966) and Blaxter *et al.*(1971) referred to the higher soluble-carbohydrate contents of spring herbage as a possible reason for its higher nutritive value. Beever *et al.* (1978) reported that the higher content of soluble carbohydrate and lower content of protein in their spring-cut (stored-frozen) herbage led to a more efficient fermentation in the rumen and a higher yield of total VFA, particularly propionate, when 950 gDM/day of each grass was fed to sheep. They also observed a greater supply of protein anterior to the duodenum in sheep fed on the spring herbage. Similarly, Ribeiro *et al.* (1981) suggested that at equal gross energy intakes of spring and autumn herbage, the amount of N entering the small intestine per unit ME intake was higher in sheep given the spring herbage. Recently, MacRae *et al.* (1985) observed greater absorption of nonammonia-N and amino-N in sheep given spring herbage in association with an improved efficiency of utilisation of ME. This supported the earlier suggestion of MacRae and Lobley (1982) that available protein absorbed from the small intestine may have some influence on the efficiency with which ruminants can utilise the VFA which they absorb from the rumen, particularly on forage-based diets.

The possibility of increasing the supply of protein entering the small intestine by using 'bypass' protein has received considerable research attention in recent years. In New Zealand, Wilson (1970), and Wilson and Brookes (1975) supplemented autumn calvers during winter with casein, formaldehyde-protected casein or formaldehyde-protected soyabean and found that the response to the supplement was improved by protection. The responses were 0.76 and 0.40 kg milk per kgDM supplements for feeding protected and unprotected casein respectively. This suggested that the protected protein had a more marked effect on the yield response than a 'normal response' obtained from energy supplements or highly degradable protein. More recently, Wilson *et al.* (1985) found that milk yield, protein yield and protein:fat ratio were all increased whereas fat yield remained unchanged because of a small reduction in milk fat concentration when concentrates containing 19% low degradable CP were supplemented to grazing dairy cows. The response of feeding low degradable protein was 0.82 kg extra milk per kg concentrate consumed.

From the previous studies in Thailand where cows were fed fresh tropical pastures or silages as basal diets, apart from ME intake, low degradable protein supplement tended to stimulate roughage intake and improved animal performance as can be seen by a higher 'apparent efficiency' of use of ME above maintenance than a high degradable protein supplement (Chapter 4 and Chapter 5). The aim of the present experiment was to determine the effect of high protein-low degradable protein meal supplementation on the performance of grazing dairy cows fed generously on autumn/winter temperate pasture. This included the effects on intake, milk yield and composition, liveweight and condition score.

8.2 MATERIALS AND METHODS

8.2.1 PRE-EXPERIMENTAL CONDITIONS

The experiment was conducted at Massey University's No.1 Dairy Farm (a Commercial Winter Milk Unit), Palmerston North, New Zealand, for 21 days (6 - 27 June 1990). Climatological data and background of the experimental site are given in Appendices 1.3 and 2.3 respectively.

8.2.1.1 Animal and Treatments

24 Friesian cows (3-7 years old, average 18.1 kg milk/cow daily, and with the calving date spread from 9/3/90 to 22/3/90) were assigned at random into two treatment groups. One group grazed on pasture alone at approximately 60 kgDM/cow daily herbage allowance (PF) while the other grazed at the same allowance (in separate halves of each paddock) and was supplemented with 3 kg/cow daily high protein meal (MF). The use of a very high allowance in the present study was to extend the results from an experiment conducted in the previous year (Annual Research Report to the Market Milk Federation of New Zealand, 1989-90) in which dairy cows were fed autumn/winter pasture at 3 level herbage allowances (13, 21 and 45 kgDM/cow daily).

Autumn calved cows, fed the generous allowance of pasture, ate 12 kgDM per day and produced 17 litres milk per day. These values were lower than would have been expected from similarly generous feeding in spring. Details of cows at the start of the experiment are presented in Table 8.2.1.

Table 8.2.1 Data for the cows before the start of the experiment.

Mean values for:	PF	MF
No. of cows	12	12
Days in milk	85±3	84±1
Milk yield (kg/day)	18.3±0.6	17.9±0.6
Fat yield (kg/day)	0.864±0.03	0.779±0.04
Protein yield (kg/day)	0.552±0.02	0.542±0.02
Lactose yield (kg/day)	0.876±0.04	0.891±0.03
Fat concentration (%)	4.74±0.18	4.36±0.22
Protein concentration (%)	3.01±0.06	3.03±0.08
Lactose concentration (%)	4.86±0.05	4.91±0.06
Liveweight (kg)	463±19	456±12
Condition score (units)	4.41±0.10	4.37±0.13

Data shown were means±SE.

8.2.1.2 Animal, Sward and Feed Management

Before the start of the experiment, the cows were fed with the main herd which was offered approximately 20 kgDM/cow daily herbage allowance plus approximately 6 kgDM silage per cow daily. They were then fed as one group on pasture alone at approximately 60 kgDM/cow daily herbage allowance for 3 days. During this time the MF cows were introduced to high protein meal (components and compositions are given in Table 8.2.2) which they ate readily.

For the next 14 days (Period I), after the 3 days adjustment period, the cows were grazed separately in two groups at an imposed allowance of approximately 60 kgDM/cow daily, while 3 kg/cow daily high protein meal was fed to the MF cows.

Following the experimental period (Period II), all cows were fed with the main herd of 170 cows at approximately 18 kgDM/cow daily herbage allowance plus approximately 7.2 kgDM silage/cow daily and the MF cows continued to receive their supplement of 3 kg/cow daily high protein meal for a further 7 days.

For a further two weeks following the cessation of high protein meal feeding (Week 2), data on milk yield and composition were collected to determine the residual effects of meal feeding.

During the experimental period, each group of cows was given a fresh area of pasture, after the morning milking each day. Each paddock was divided longitudinally into two equal areas, one for each treatment group. These areas were subsequently divided into 2-3 breaks depending on the size of paddock and the pregrazing herbage mass. Each break was occupied by either the PF or MF groups daily. The electric fence was used to prevent the cows from "back grazing" the area grazed on the previous day.

The high protein meal supplement was offered to the MF group of cows once daily in communal troughs, immediately after morning milking. These cows were allowed access to the meal for 15-20 minutes before they returned to pasture. The MF cows consumed all the supplement offered.

8.2.1.3 Pastures and Supplements

The pastures comprised mainly perennial ryegrass and white clover. The area used to conduct the experiment was 9.6 ha divided into 4 paddocks.

The feed components and chemical compositions of the high protein meal supplement are given in Table 8.2.2. The concentrate was thoroughly mixed by vertical central spin mixer without pelleting.

Table 8.2.2 Concentrate components and chemical compositions.

Components (kg/100kg)	
Brewers' grain	50
'Fat extracted' soyabean meal	30
Full fat soyabeans	20
Chemical composition	
Dry matter (%)	89.5
Crude protein (%)	33.1
Ash (%)	5.1
In vitro	
Dry matter digestibility (%)	76.2
Organic matter digestibility (%)	77.5
Digestible organic matter (%)	73.6
Estimated metabolisable energy (MJ/kgDM)[1/]	11.8
Estimated protein degradability[2/]	0.6

1/ ME = 0.16DOMD (MAFF, 1975).

2/ Estimated from protein degradability values of feedstuffs given by ARC (1980).

8.2.2 MEASUREMENTS

Unless otherwise stated, the methods and equipment used to make the measurements described below are those detailed in Appendix 3.

8.2.2.1 Feed Measurements

Pre and post grazing herbage yields were measured on 8 occasions during the experimental period. On each occasion, pasture enclosed within ten 0.1875 m^2 quadrats was cut to ground level for each treatment break, with a motor driven shearing-handpiece.

In this experiment, estimates of feed intake were also obtained from faecal output using slow-release Cr_2O_3 capsules as an indigestible marker. The procedure used was detailed in Appendix 3..

The sampling procedure used for the cutting technique was that of a stratified random sampling described by Meijs *et al.* (1982). The indigestible marker technique used was described by Le Du and Penning (1982).

Where cut herbage was taken before grazing, a subsample of dried herbage bulked from each treatment within each paddock was ground through 1-mm sieve and analysed for N concentration (%, Kjeldahl method), Ash concentration (%, 500°C overnight) and *in vitro* digestibility (%, Roughan and Holland, 1977).

While the experiment was in progress, the MF cows were seen to graze selectively on the upper strata of the pasture while the PF cows grazed down to the middle and bottom strata of the pastures. The three strata; top, middle and bottom; were collected by cutting with a shearing hand piece at approximately 15, 8 cm height and ground level and the different portions were analysed for OM, N and *in vitro* digestibility. *In vivo* digestibilities of the top and bottom strata were also measured using 8 sheep fed *ad libitum* different pasture to that used in the grazing experiment but similar in composition and mass (See Appendix 3.2.3.2 for management of animals, pasture cutting technique, feeding and measurements).

During pre- and post-experimental period, grass meter readings (Earle and McGowan, 1979) were taken occasionally to estimate herbage mass before and after grazing by the whole herd.

The high protein meal samples were taken in duplicate from each batch at the time of mixing. They were then bulked, thoroughly mixed and a subsample was taken for chemical analysis.

8.2.2.2 Animal Measurements

Pre-grazing herbage mass, residual herbage mass and daily herbage allowance were used as defined by Hodgson (1977).

Over the experimental period of 21 days, individual morning and evening milk yields were recorded on 6 occasions. Aliquot milk samples were taken at this time for analyses of concentrations of milk fat, milk protein and milk lactose (Milko Scan, 140A/B, Foss Electric, Denmark).

Liveweight and condition score were measured after morning milking on 3 occasions; at the start, after two weeks and at the end of the experimental period.

8.2.3 STATISTICAL ANALYSIS

All data were analysed using the Statistic Analysis System (SAS) computing package (SAS Institute Inc., Cary, NC 27512-8000, USA. 1985,86,87).

Sward (HM, RHM, HA), intake (DMI and MEI) and liveweight change data were analysed using analysis of variance (Steel and Torrie,1986). The details of the model used to define the data was that described in Appendix 4.1.

Liveweight and condition score were analysed using analysis of covariance as described in Appendix 4.2.

Yields of milk, milk fat, milk protein and milk lactose, and milk compositions were analysed using the repeated measurement analysis of covariance (Gill and Hafs, 1971; Finn, 1974; Morrison, 1976; Bryant and Gillings, 1985) as described in Appendix 4.3.

8.3 RESULTS

8.3.1 CHEMICAL ANALYSIS OF THE FEEDS

The chemical analyses of the pastures used during the experiment are given in Table 8.3.1. The quality of pastures offered to both treatments were similar (as expected because they were in the same paddocks).

Table 8.3.1 Data for the chemical analyses of pastures (cut to ground level), PF = pasture fed only; MF = meal supplement; HM = pre-grazing herbage mass; DMD = dry matter digestibility; OMD = organic matter digestibility; DOMD = digestible organic matter digestibility; CP = crude protein; ME = metabolisable energy concentration.

Paddock No.		HM	in vitro %DMD	%OMD	%DOMD	%CP	%ASH	ME[1/] (MJ/kgDM)
1	PF	2638	75.2	76.3	68.1	22.6	10.7	10.9
	MF	2700	76.1	78.8	69.4	22.1	11.8	11.1
2	PF	2313	74.0	75.5	65.6	21.0	13.1	10.5
	MF	2211	76.9	77.5	69.4	21.1	10.4	11.1
3	PF	2452	78.2	79.9	69.1	20.2	13.5	11.1
	MF	2670	76.6	79.2	69.4	20.2	12.3	10.9
4	PF	1746	82.5	84.3	74.4	25.1	11.8	11.9
	MF	1803	81.7	82.8	74.4	23.4	10.1	11.5
MEAN	**PF**	**2287**	**77.5**	**79.0**	**69.3**	**22.2**	**12.3**	**11.1**
	MF	**2346**	**78.0**	**78.9**	**70.1**	**21.7**	**11.2**	**11.2**

[1/] ME = 0.16 DOMD (MAFF, 1975).

The chemical analyses of the pasture strata are shown in Table 8.3.2. The top strata showed higher DMD, OMD, DOMD, CP and estimated ME than the middle and bottom strata.

Table 8.3.2 Chemical analyses of the pasture strata.

Herbage strata	DMD (%)	OMD (%)	DOMD (%)	CP (%)	Ash (%)	ME[1/] (MJ/kgDM)
Top (>15cm)	77.7	78.2	69.8	27.2	10.7	11.2
Middle (8-15cm)	75.4	76.4	67.9	25.3	11.1	10.9
Bottom (0-8cm)	73.5	75.7	66.4	19.6	12.3	10.6

[1/] ME = 0.16DOMD (MAFF, 1975).

Mean values for dry matter intake of sheep fed the top and bottom strata of pasture together with the corresponding *in vivo* and *in vitro* digestibilities are given in Table 8.3.3. Dry matter intakes of the pasture strata were similar ($p>0.05$) between the two groups. The digestibilities of the top strata were higher than of the bottom strata ($p<0.05$). Both *in vitro* and *in vivo* digestibilities showed similar differences in digestibilities although the absolute values for *in vivo* digestibility tended to be higher than those for *in vitro* digestibility. This was because of selective eating behaviour of the animals for the *in vivo* digestibility determination.

Table 8.3.3 DMI, *in vivo* and *in vitro* DMD, OMD and DOMD values from sheep fed the top or bottom strata of pasture.

	TOP	BOTTOM	SEM	Sig.
DMI (kg/day)	1.18	1.26	0.16	NS
In vivo				
DMD (%)	78.76	74.46	1.19	*
OMD (%)	80.96	77.35	1.06	*
DOMD (%)	70.43	65.58	0.82	**
In vitro				
DMD (%)	75.60	73.20	-	-
OMD (%)	76.00	74.33	-	-
DOMD (%)	67.60	66.15	-	-

8.3.2 SWARD CHARACTERISTICS

8.3.2.1 Pre-grazing Herbage Mass and Residual Herbage Mass

The mean values and ANOVA for HM and RHM are given in Table 8.3.4.

Although there was consistently more RHM in the MF pastures (difference of 149 kgDM/ha) the mean values of HM and RHM for the PF and MF treatment were not significantly different ($p>0.05$).

Table 8.3.4 Mean values for pregrazing herbage mass (kgDM/ha, HM) and residual herbage mass (kgDM/ha, RHM) of the unsupplemented and supplemented cows.

	HM				RHM			
Pd.No.	PF	MF	SEM	Sig.	PF	MF	SEM	Sig.
1	2638	2700			1825	2023		
2	2313	2211			1547	1566		
3	2452	2670			1824	2116		
4	1746	1803			1290	1376		
Mean	2287	2346	287	NS	1621	1770	219	NS

SDw 376·84

8.3.2.2 DM Allowance and DM Intake

Mean values for DM allowance and intake measured by 'cutting' and 'Cr_2O_3' methods are presented in Table 8.3.5. Herbage DM allowance between the PF and MF treatments were not significantly different ($p>0.05$). It was assumed that the MF cows ate only the top strata and that the diets eaten by the PF cows consisted of 50% from

the top strata and 50% from the lower strata. Thus for the estimate of DM intake of the MF cows, the *in vitro* DMD value of the top strata was used and for the PF cows the mean value between the top and the bottom strata was used. Pasture DM intake measured by 'cutting' method showed significant difference between the groups ($p<0.01$) while those measured by 'Cr_2O_3' method were not significant different ($p>0.05$).

When DM allowance was expressed as total DM allowance (pasture plus concentrate) and when total DM intake was used, both total DM allowance and intake measured by 'cutting' method were similar ($p>0.05$) for the two treatments. The total DM intake measured by 'Cr_2O_3' method were also similar for both treatments ($p>0.05$).

Calculated substitution rate which is defined as a reduction in herbage intake (kgDM) when 1 kgDM supplement was consumed, was 0.71 by 'cutting' method and was 0.45 by 'Cr_2O_3' method.

Table 8.3.5 Mean values for feed dry matter allowance (kgDM/cow daily) and dry matter intake (kgDM/cow daily) of the unsupplemented and supplemented cows.

	DM allowance				DM intake			
Mean values for:	PF	MF	SEM	Sig.	PF	MF	SEM	Sig.
As pasture								
Cutting method	62.7	62.9	2.7	NS	17.5	15.6	0.4	**
Cr_2O_3 method 1/					14.0	12.8	0.9	NS
As supplement	-	2.7	-	-	-	2.7	-	-
Total								
Cutting method	62.7	65.6	2.7	NS	17.5	18.2	0.4	NS
Cr_2O_3 method					14.0	15.5	0.9	NS
Substitution rate	'cutting'				0.71			
	'Cr_2O_3'				0.45			

1/ n = 5 and 7 for the PF and MF groups respectively.

8.3.2.3 ME Allowance and ME Intake

Mean values for estimated ME allowance and ME intake for both treatment groups are shown in Table 8.3.6. Pasture ME allowance and total ME allowance were similar for both groups ($p>0.05$). Pasture ME intake and total ME intake measured by 'cutting' method differed significantly between group ($p<0.01$ and $p<0.05$ respectively), however, pasture ME intake and total ME intake measured by 'Cr_2O_3' method were similar for both groups ($p>0.05$).

Table 8.3.6 Mean values for estimated metabolisable energy allowance and metabolisable energy intake (MJ/cow daily) of the unsupplemented and supplemented cows.

	ME allowance				ME intake			
Mean values for:	PF	MF	SEM	Sig.	PF	MF	SEM	Sig.
As pasture								
Cutting tech.	696	704	30	NS	194	174	4	**
Cr_2O_3	-	-	-	-	156	144	10	NS
As supplement	-	32	-	-	-	32	-	-
Total								
Cutting	696	736	30	NS	194	206	4	*
Cr_2O_3	-	-	-	-	156	176	10	NS

8.3.3 ANIMAL PERFORMANCE

The following results reported are adjusted means using the initial corresponding performances as covariates.

8.3.3.1 Yields of Milk, Milk Fat, Milk Protein and Milk Lactose

Mean values for milk yield, milk fat yield, milk protein yield and milk lactose yields are presented in Table 8.3.7 and illustrated in Figures 8.1 and 8.2. Yields of milk, milk protein and milk lactose were increased by high protein meal supplementation in both periods, while fat yield was enhanced significantly ($p<).05$) only in the first period.

By the 2nd week after the cessation of meal feeding, fat and protein yields from PF and MF cows were not statistically different, however, the MF cows were still producing a greater milk yield ($p<0.05$; Table 8.3.7).

The response to high protein meal supplementation was 0.82 and 1.03 kg milk per kgDM concentrate eaten in period I and II respectively. The responses to 1 kg concentrate DM eaten were 26 and 30 g fat, and 26 and 37 g protein in Period I and II respectively. When this response was expressed as kg milk/kg extra DM actually eaten (after allowing for the substitution of meal for pasture), it was much higher (2.87 kg milk/kg extra DM consumed by 'cutting' method and 1.47 kg milk/kg extra DM intake by 'Cr_2O_3' method for period I).

Table 8.3.7 Mean values for yields of milk, milk fat, milk protein and milk lactose of the unsupplemented and supplemented cows.

Mean values for:	PF	MF	SEM	Sig.
Milk Yield (kg/cow daily)				
Initial	18.3	17.9	0.6	NS
Period I	20.3	22.5	0.5	**
Period II	18.1	20.8	0.5	**
Week 2	14.7	16.5	0.5	*
Fat Yield (kg/cow daily)				
Initial	0.86	0.78	0.03	NS
Period I	0.87	0.94	0.02	*
Period II	0.83	0.91	0.03	NS
Week 2	0.66	0.72	0.03	NS
Protein Yield (kg/cow daily)				
Initial	0.55	0.54	0.02	NS
Period I	0.75	0.82	0.02	**
Period II	0.63	0.73	0.02	**
Week 2	0.47	0.51	0.02	NS
Lactose Yield (kg/cow daily)				
Initial	0.88	0.89	0.03	NS
Period I	1.03	1.11	0.02	*
Period II	0.94	1.06	0.03	**

Means adjusted using the initial corresponding yields as covariates

Period I = at herbage allowance of approx. 60 kgDM/cow daily

Period II = at herbage allowance of approx. 18 kgDM/cow daily plus approx. 7.2 kgDM silage/cow daily

Week 2 = the 2nd week after the cessation of meal feeding and still fed as Period II.

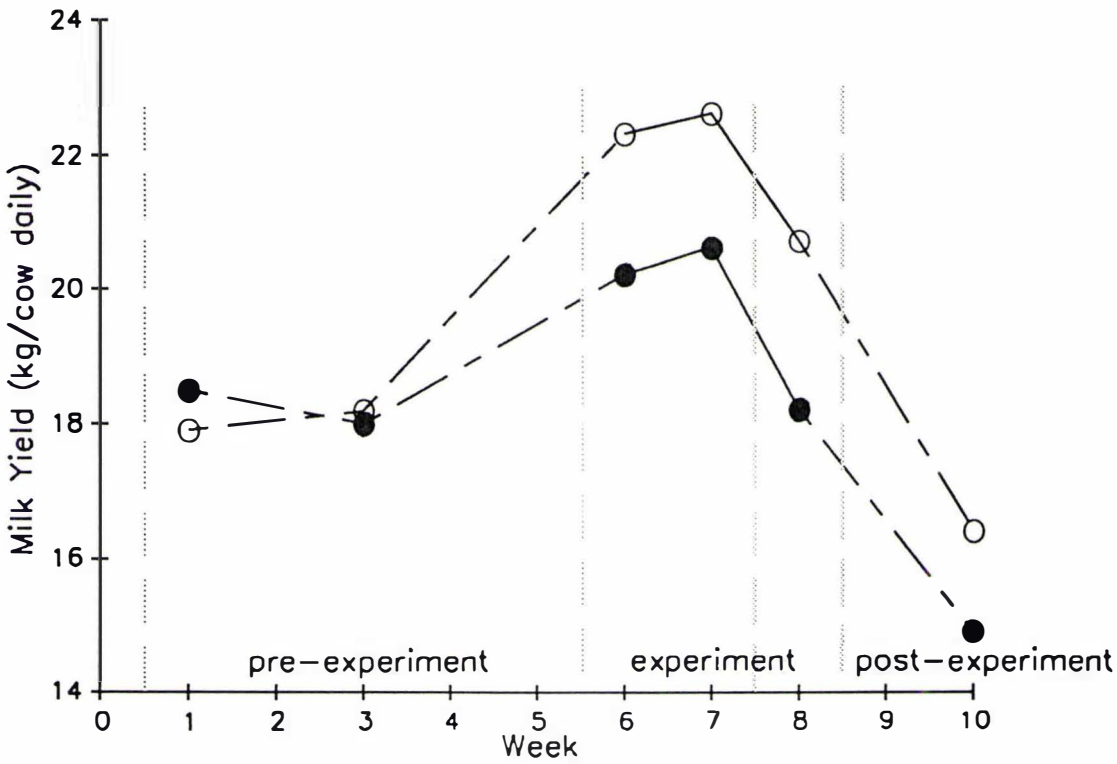

Figure 8.1 The effect of high protein (low degradable) concentrate supplementation on milk yield.
Unsupplemented cows (PF) shown (●).
Supplemented cows (MF) shown (o).

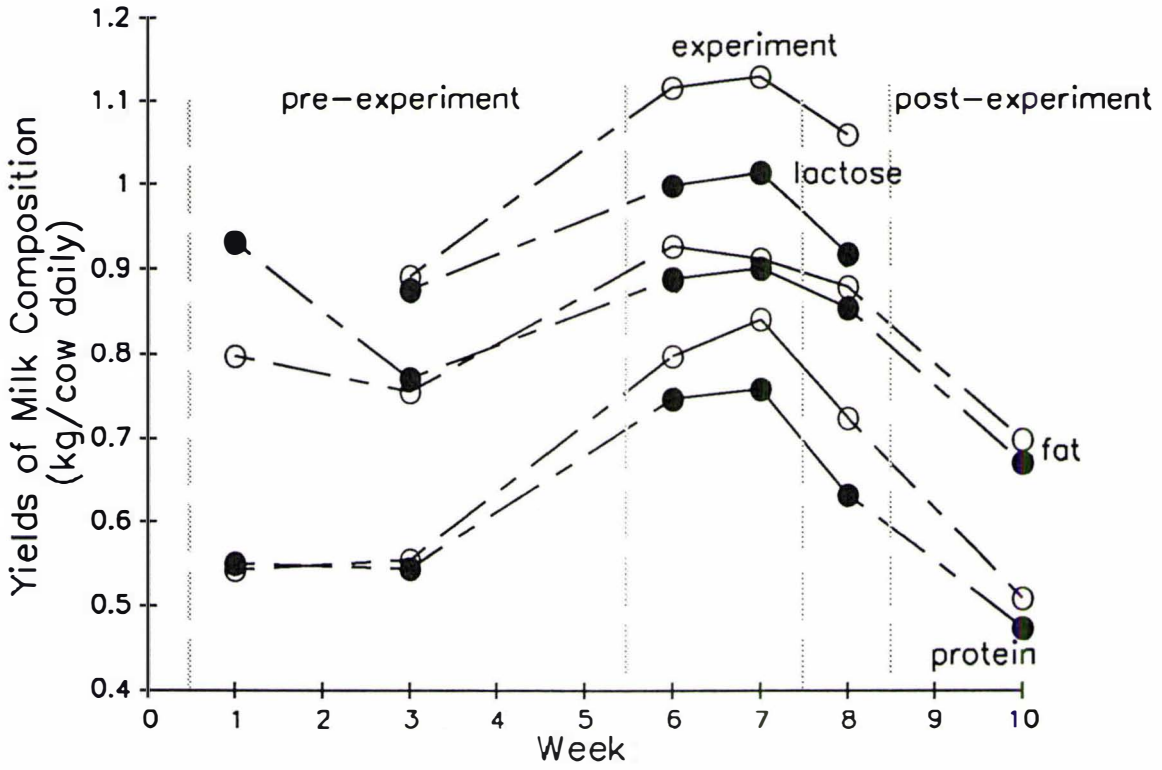

Figure 8.2 The effect of high protein (low degradable) concentrate supplementation on yields of milk fat, milk protein and milk lactose. (●, o) as in Figure 8.1.

8.3.3.2 Concentrations of Milk Fat, Milk Protein and Milk lactose

Mean values for milk composition are given in Table 8.3.8 and illustrated in Figure 8.3. No significant difference in milk composition was observed between the two groups in both periods. This suggested that milk composition was unaffected by supplementation in this study. Of interest, protein concentration in both groups was dramatically increased by *ad libitum* pasture feeding when compared with the data recorded in the initial (pre-experiment) period (See Table 8.3.8) and then reduced again when cows returned to a low level of pasture feeding. This suggested that for protein concentration, level of feeding was more important than the nature of the feed. Lactose concentration in both groups was also increased by generously feeding compared to the initial preexperimental period.

Table 8.3.8 Mean values for concentrations of milk fat, milk protein and milk lactose (%) of the unsupplemented and supplemented cows.

Mean values for:	PF	MF	SEM	Sig.
Fat				
Initial	4.74	4.36	0.20	NS
Period I	4.28	4.28	0.08	NS
Period II	4.58	4.45	0.12	NS
Week 2	4.39	4.46	0.16	NS
Protein				
Initial	3.01	3.03	0.07	NS
Period I	3.70	3.68	0.04	NS
Period II	3.48	3.51	0.06	NS
Week 2	3.20	3.21	0.08	NS
Lactose				
Initial	4.86	4.91	0.05	NS
Period I	4.97	4.99	0.02	NS
Period II	5.08	5.08	0.03	NS

Means adjusted using the initial corresponding concentrations as covariates.
Period I, Period II and Week 2 as for Table 8.3.7.

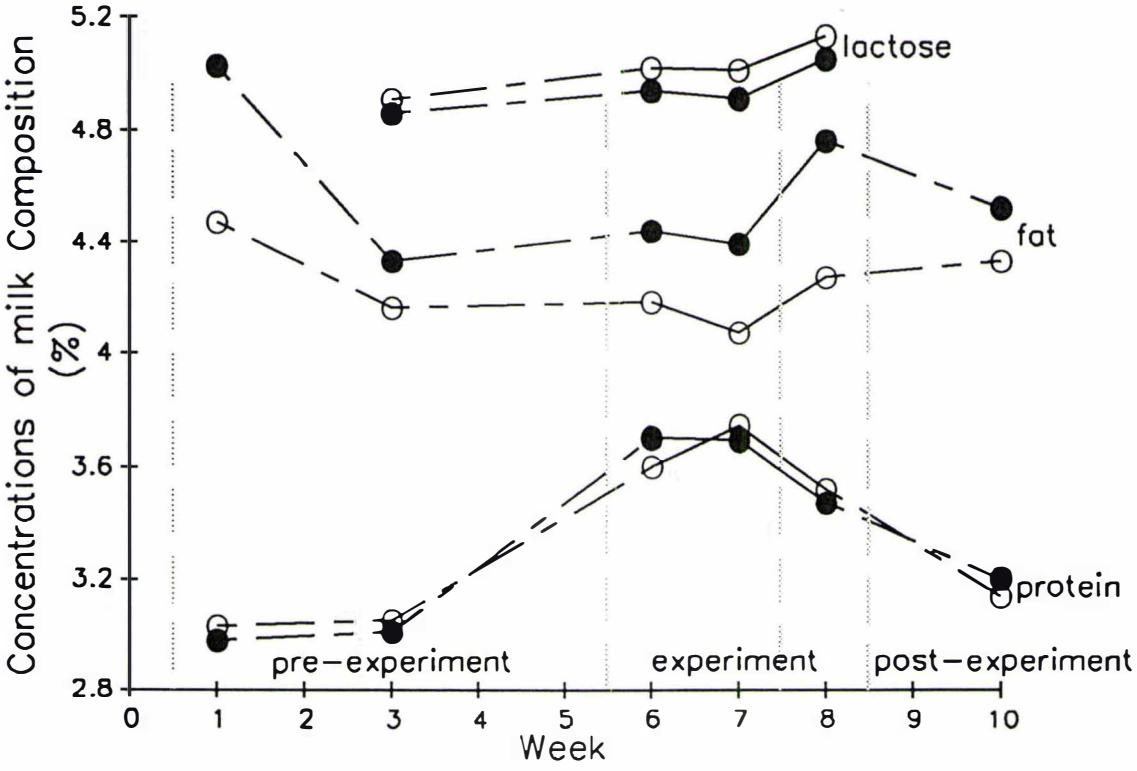

Figure 8.3 The effect of high protein (low degradable) concentrate supplementation on concentrations of milk fat, milk protein and milk lactose. (●, o) as in Figure 8.1.

8.3.3.3 Liveweight and Condition Score

Mean values for initial and final liveweight, condition score, and liveweight and condition score change are shown in Table 8.3.9. The initial liveweight of both groups was similar (463 and 456 kg for the PF and MF cows respectively). The high protein meal supplementation did not affect liveweight at the end of period I but it did at the end of period II. Liveweight change was unaffected by supplementation during Period I, but it differed ($p<0.05$) significantly during Period II.

Both condition score at the end of period I and condition score change over period I were improved by supplementation.

Table 8.3.9 Mean values for initial weight, final weight (kg), liveweight change (kg/day), initial condition score, final score (units) and condition score change (unit/week) of the unsupplemented and supplemented cows.

Mean values for:	PF	MF	SEM	Sig.
Initial weight	463	456	5.3	NS
Final weight				
Period I	471	482	3.9	NS
Period II	470	490	3.8	**
LW change				
Period I	+0.75	+1.63	0.47	NS
Period II	-0.10	+1.17	0.41	**
Initial CS	4.34	4.26	0.26	NS
Final CS				
Period I	4.48	4.72	0.06	*
Period II	-	-	-	-
CS change				
Period I	0.08	0.26	0.08	*
Period II	-	-	-	-

Means adjusted using the initial corresponding concentrations as covariates.
Period I, Period II and Week 2 as for Table 8.3.7.

8.3.4 OVERALL RELATIONSHIPS BETWEEN NUTRITION AND PERFORMANCE

Using the assumed degradability values of 0.80 for pasture and 0.60 for the concentrate (ARC, 1980), the estimated supply of RDP and UDP to the cows was calculated (Table 8.3.10). The resulting RDP/ME ratios in the rations consumed are also presented in this Table. Due to the substitution effect and the assumed low degradability of the concentrate, both groups had similar intakes of RDP. In contrast, the intake of UDP was markedly higher in the supplemented cows than in unsupplemented cows. The RDP/ME ratios between the two groups were similar and were much higher than suggested by ARC (1984) of 8.1 g/MJ.

By combining the data for milk yield and liveweight change (in energy terms, MJ), it was possible to examine the influence of concentrate supplementation on the 'apparent' utilisation of metabolisable energy intake (Table 8.3.11). Despite the substitution effect, supplementation of pasture with concentrate clearly increased ME intake. Estimated MEI was apparently also used more efficiently by the MF group compared with the PF cows.

Using the measured values for animal performance, and the assumed values for rumen degradability of protein in pasture (0.80) and concentrate (0.60) (ARC, 1908), the intakes of RDP and UDP, as given by the ARC (1980), have been calculated (Table 8.3.12). The *in vivo* and *in vitro* protein degradabilities of temperate pasture and various feedstuffs have been extensively reviewed by ARC (1980, 1984). Recently, Corbett and Pickering (1983) reported the values range from 0.82 to 0.97, and only with the later season was significant reduction observed (0.72). The values of 0.81, 0.85 and 0.84 for early-, mid- and late-season ryegrass were also reported by Cammell *et al.* (1983). The present study adopted a value for protein degradability of pasture of 0.80 as suggested by ARC (1980, 1984). The protein degradability values for brewers' grain and soyabean meal, the feedstuffs used in the present experiment, were also obtained from ARC (1980, 1984) and those reviewed in this thesis (Chapter 5).

It is clear from the estimates shown in this Table that, whatever methods of estimating herbage intake were used, the supplies of both RDP and UDP were greater than the requirements. The supply of RDP was was about twice the requirement. The supply of UDP also higher than the requirement.

Table 8.3.10 The supply of rumen degradable protein (RDP), undegradable protein (UDP) and the ratio of RDP/metabolisable energy intake (MEI, g/MJ).

Details:	PF	MF
Cutting		
RDP supply (g/day)		
As pasture	3106	2698
As concentrates	-	532
Total	3106	3230
UDP supply (g/day)		
As pasture	776	675
As concentrates	-	355
Total	776	1030
Total ME intake (MJ/day)	194	206
RDP/Total ME intake (g/MJ)	16.0	15.7
Cr_2O_3		
RDP supply (g/day)		
As pasture	2486	2222
As concentrates	-	532
Total	2486	2754
UDP supply (g/day)		
As pasture	622	556
As concentrates	-	355
Total	622	911
Total ME intake (MJ/day)	156	176
RDP/Total ME intake (g/MJ)	15.9	15.6

Table 8.3.11 Estimates of the partitioning of metabolisable energy intake, by treatment groups in Period I. (MJME/day)

Details:	PF	MF	MF-PF
Cutting			
Total ME intake	194	206	+12
ME requirement for maintenance 1/	60	59	-1
MEI - ME_m	134	147	+13
Net energy in milk 2/	78	86	+8
Net energy in liveweight 3/	16	35	+19
Net energy retention 4/	94	121	+27
'Apparent' efficiency 5/	0.70	0.82	+0.12
Cr_2O_3			
Total ME intake	156	176	+20
ME requirement for maintenance 1/	60	59	-1
MEI - ME_m	96	117	+21
Net energy in milk 2/	78	86	+8
Net energy in liveweight 3/	16	35	+19
Net energy retention 4/	94	121	+27
'Apparent' efficiency 5/	0.98	1.03	+0.05

1/ = $0.60LW^{0.75}$.
2/ = Equation 4 of Tyrrell and Reid (1965).
3/ = 21.5 MJ/kgLW change.
4/ = Net energy in milk plus liveweight.
5/ = Net energy retention/MEI - ME_m.

Table 8.3.12 The estimated supply of rumen degradable protein (g/day; RDP) and undegradable protein (g/day; UDP) to the tissues of the cows.

Details:	PF	MF
Cutting		
RDP requirement[1/]	1513	1607
RDP supply	3106	3230
RDP surplus	1593	1623
Tissue protein supply by[2/] microbial protein	640	683
Total tissue protein requirement[3/]	813	1015
UDP requirement[4/]	329	631
UDP supply	776	1030
UDP surplus	447	399
Cr_2O_3		
RDP requirement[1/]	1217	1373
RDP supply	2486	2754
RDP surplus	1269	1381
Tissue protein supply by[2/] microbial protein	515	581
Total tissue protein requirement[3/]	813	1015
UDP requirement[4/]	566	825
UDP supply	622	911
UDP surplus	56	86

1/ = 7.8ME (ARC, 1984).
2/ = 3.3ME (ARC,1984).
3/ = estimated from animal production according to ARC (1980).
4/ = 1.9 (Total tissue protein requirement - 3.3ME). ARC (1980).

8.3.5 SUMMARY OF THE RESULTS

1. Autumn calved cows, fed generously (60 kgDM/cow daily) on pasture alone (unsupplemented group), ate 17.5 kgDM/day and produced 20.3 litres milk per day. (Pasture DM disappearance technique)

2. Differences in daily herbage intake between the MF and PF groups estimated by 'cutting' and 'Cr_2O_3' were 1.9 and 1.5 kgDM/cow respectively.

3. Concentrate supplementation reduced herbage DM intake by 0.4-0.7 kg/kgDM concentrate eaten.

4. High protein concentrate supplementation increased yields of milk, milk fat, milk protein and milk lactose (0.8 kg, 26 g, 26 g and 30 g per kg concentrate DM eaten respectively) and liveweight gain (330 g/kgDM concentrate eaten).

8.4 DISCUSSION

8.4.1 EFFECT OF HIGH PROTEIN CONCENTRATE SUPPLEMENTATION ON FEED INTAKE AND SWARD CHARACTERISTICS

8.4.1.1 Digestibility of Pasture

The *in vitro* digestibility of all samples was high, but it varied between paddocks (Table 8.3.1) and showed a negative relation to pregrazing herbage mass i.e. digestibility decreased as herbage mass increased. The relatively high digestibility of more than 80% in paddock 4 is because of the new growth of pasture with 1800 kgDM/ha herbage mass compared to 76% digestibility with 2700 kgDM/ha herbage mass of paddock 1. With the exception of the digestibility value of Paddock 4, the average digestibility of pasture was in agreement with those values obtained from pasture strata estimated *in vitro*.

The samples of pasture strata were only taken from Paddocks 1, 2 and 3 due to the low mass in Paddock 4. The results clearly showed that digestibility of the lower strata within the pasture profile was lower than that in the higher strata. Holmes *et al.* (1992) observed that digestibility was lowest in the sward base, and increased towards the sward surface. The observed trends in the digestibility of the total herbage in each strata were similar to those reported by Clark *et al.* (1974a,b) and O'Sullivan (1984). The differences in herbage quality between strata were due to the differences in their composition. The lower strata had a lower percentage of grass leaf and clover and a higher percentage of senescent matter and grass stem than the top strata (Hoogendoorn *et al.*, 1992).

Although the (sheep) *in vivo* digestibility data were obtained from a different pasture than that used in the grazing experiment, the 'top' and 'bottom' portions were taken from a pasture of similar composition and mass (approximately 2500 kgDM/ha) during the same period. However, the digestibility values of the sheep pastures were slightly lower than those measured *in vitro* for the cow pastures.

For the sheep and the cow pastures, the digestibilities of the top strata were higher than the bottom strata both estimated by *in vitro* and *in vivo* methods (Table 8.3.3). However, for the sheep pastures, the *in vivo* digestibility value tended to be higher than the *in vitro* value. This was probably due to the selective eating behaviour of the sheep. The major factor contributing to this difference was probably due to the difficulty of collection of the samples that represent the actual consumption by the animals.

8.4.1.2 Measurements of Intake

Pasture DM intakes were measured by both the sward cutting technique and by use of Cr_2O_3 indigestible marker. The sward cutting technique provided information on the herbage mass and, residual herbage mass and herbage allowance, and it was unaffected by concentrate supplementation, in contrast to methods based on indigestible marker technique (Milne *et al.*,1981). However, the sward cutting technique only gives an average intake for the whole group each day while indigestible marker provides estimates of intake by individual cows for the whole period of measurement.

Mean pre-grazing HM of PF and MF swards were 2287 and 2346 kgDM/ha respectively in the range of values where DM intake is likely to be unaffected by HM (Combellas and Hodgson, 1979; Meijs, 1981). Combellas and Hodgson (1979) reported that herbage intake of grazing cows was near maximum when grazing efficiency, defined as herbage intake expressed as a proportion of the HA, was 50% or less. In New Zealand, Glassey *et al.* (1980) reported that herbage intake by grazing dairy cows was unaffected by herbage allowance of approximately 33 kgDM/cow daily and residual herbage mass of approximately 1550 kgDM/ha, and calculated grazing efficiency of 43%. Grazing efficiencies of the PF and MF cows were 28% and 25% respectively in the present study suggesting that herbage intake was not limited by herbage availability or residual herbage mass.

Herbage intakes estimated by the Cr_2O_3 indigestible marker method were slightly lower than those estimated by the difference method and were not significantly different between the two groups (14.0 and 12.8 kgDM/cow daily for the PF and MF respectively, $p>0.05$). However, herbage intakes estimated by the sward cutting technique were significantly different between the PF and MF cows (17.5 and 15.6 kgDM/cow daily respectively, $p<0.01$).

Measurement of intake by Cr_2O_3 indigestible marker technique is largely dependent on accurate estimate of faecal output and diet digestibility. In the present study, from 12 cows in each group that were dosed by Cr_2O_3 slow-release capsules, only 7 and 5 from the MF and PF cows respectively showed a considerable concentration of the marker in the analysed faeces while the others had probably lost their capsules. The resulting estimate of intake by this method was more variable than the 'cutting' technique as can be seen by larger standard error (Table 8.3.5). Variations in faecal output estimation would have affected the estimates of intake. However, the major contribution to accurate estimates of intake by Cr_2O_3 method was that of digestibility of the diet consumed. As intake estimated by this method was a function of faecal output divided by (1 - digestibility), error in estimation of faecal output would have led to equivalent error in intake but an error in the estimation of digestibility would have led to a proportionately larger error in (1 - digestibility) and consequently in intake.

In the present study, concentrates as well as pasture was fed to the MF cows. The digestion of one feed was therefore not independent of the other. When a concentrate is fed with the pasture, the availability of rapidly fermentable carbohydrate in the concentrate would be expected to modify the rumen fermentation pattern to some degree and this has been reported to lower the digestibility of the forage (Milne *et al.*, 1981). No allowance has been made for this circumstance when estimations of intake were made because the ration was designed to have minimal effects in the rumen (i.e. relatively low proportion of readily available polysaccharides).

8.4.1.3 Effect on Substitution Rate

The substitution rate, which is defined as the reduction in herbage intake when 1 kgDM supplement was consumed, found in the present study was 0.71 from cutting technique and 0.45 from Cr_2O_3 technique, when supplemented cows consumed 2.7 kgDM concentrates/cow daily. The substitution rates for cows given generous herbage allowance varied between 0.03 and 0.79 kgDM/kg concentrate DM eaten (Jennings and Holmes, 1984; Meijs and Hoekstra, 1984; Arriga-Jordan and Holmes, 1986; Meijs, 1986; Stakelum, 1986a,b,c). The variation in substitution rates between studies have been attributed to differences in herbage digestibility, levels of concentrates feeding, restricted access to herbage causing low herbage intake.

Meijs and Hoekstra (1984) suggested that the effect of concentrate feeding on herbage intake of grazing cows depends largely on the level of daily herbage allowance. The present study was not designed to compare the effects of either the levels of herbage allowance or the levels of concentrates supplements on herbage intake. However, when dairy cows were generously fed (33 kgDM/cow daily herbage DM allowance), and given approximate 3 kgDM concentrates intake (at an approximate herbage intake of unsupplemented cows of 15.5 kgDM/cow daily which is similar to the present study), Meijs and Hoekstra (1984) and Grainger (1987) found substitution rates of 0.79 and 0.69 respectively.

8.4.1.4 Effect on Residual Herbage Mass

Since residual herbage mass is the consequence of the difference between pre-grazing herbage mass and herbage intake, increases in residual herbage mass of the MF treatment would be expected and were presumably caused by reductions in herbage intake due to concentrate supplementation. Increases in residual herbage mass would also allow animals to consume forage of higher digestibility from the upper strata. Residual herbage mass was increased by concentrate feeding in the present study (149 kgDM/ha), although the increase was not statistically significant. This effect of supplementation on RHM has been observed by several workers (Stockdale and Trigg, 1985; Stakelum, 1986a; Grainger, 1987; Suksombat, 1988).

Grainger (1987), at an allowance of 33 kgDM/cow daily, reported substitution rate of 0.69 kgDM/ kg concentrate DM eaten and consequently supplemented cows left 111 kgDM/ha RHM higher than unsupplemented cows when 3.2 kgDM/cow daily concentrate was eaten by supplemented cows. The results of the present study corresponded well with those of Grainger (1987).

8.4.2 EFFECT OF HIGH PROTEIN CONCENTRATE SUPPLEMENTATION ON ANIMAL PERFORMANCE

8.4.2.1 Yields of Milk, Milk Fat, Milk Protein and Milk Lactose

The objective of the present study was to determine the effects of a high protein and relatively low degradability concentrate supplemented to grazing dairy cows at very high herbage allowance of winter pasture on animal performance. Although most experiments have always reported the response in terms of kg milk per kg concentrate DM eaten, the response in terms of kg milk per kg extra DM eaten will also be considered in the following discussion since it will give a measure of the response which can be interpreted in biological terms.

In the present study, supplementation with the high protein meal increased the yields of milk, milk protein and milk lactose in both Period I and II while milk fat was increased only in Period I. The cows, which consumed 2.7 kgDM as concentrates, produced 10% and 13% more milk than unsupplemented cows, in Periods I and II respectively. The mean response to 1 kgDM concentrate consumption was 0.82 and 1.03 kg milk in Periods I and II respectively, which were much higher than those reported by Leaver *et al* (1968).

In the experiments reviewed by Leaver *et al* (1968), the mean response in milk yield was 0.32 kg/kg concentrate consumed. Journet and Demarquilly (1979) reviewed ten experiments where cows were initially yielding over 25 kg milk/day, were given concentrate supplement. The mean response was 0.4 kg milk/kg additional concentrate. Those results were obtained from experiments varying in type of concentrates, level of concentrate feeding and level of pasture allowance. The concentrates used in the present experiment were protein-rich and of low protein degradability. When a comparison is made with experiments that used protected protein or low-degraded protein concentrates (Wilson, 1970; Wilson and Brookes, 1975; Wilson *et al.*,1985), the responses were similar to the present study. Wilson *et al.* (1985) supplemented low-degraded protein meal (190 gCP/kgDM) to grazing cows and found that the response to 1 kgDM concentrate was 0.86 kg milk.

Rogers *et al.* (1983) reviewed 8 experiments where protein (from lupins, soyabean meal, sunflower seed meal and cotton seed meal) or energy (from Oats and Barley) concentrates were supplemented to dairy cows and reported that, 4 out of 8 experiments showed greater responses to protein than energy (ranging from 0.3 to 1.0 kg milk/day) concentrates. They suggested that the increased yield of cows fed protein supplements could be accounted for by their increased intakes.

When the response in milk yield is expressed per kg extra DM actually eaten (extra concentrate minus reduction in pasture intake), this represents 3.1 and 1.5 kg of milk per kg extra feed DM eaten when these were measured by cutting and Cr_2O_3 technique respectively. From feeding tables it might be expected that 1 kg meal, which should provide approximately 12 MJ ME would increase milk yield by about 2 kg if all the energy was used for milk production. The response obtained are therefore very high and suggest that the quality of the ration consumed by the MF cows was improved relative to the PF ration.

In an experiment by Grainger (1987) where grazing dairy cows were given a high pasture allowance (33 kgDM/cow daily) and consumed 3 kgDM/day of concentrate the response of milk yield to 1 kg extra DM consumed was 0.99 kg, a figure which is below the responses estimated in the present study from the two methods.

The relatively small response in milk yield to supplementary concentrates when expressed as kg milk/kg concentrate DM eaten, compared with response from extra feed DM eaten is due to the fact that when concentrates were eaten the intake of herbage decreased therefore the animal's total intake of DM was increased by less than the quantity of concentrate eaten. In the present study, the total DM intake of supplemented cows increased by 0.7 and 1.5 kg, representing 0.26 and 0.56 increases in total DM intake/kgDM concentrate when pasture intake was estimated by cutting and Cr_2O_3 methods respectively.

Table 8.4.1 **Changes in intake of pasture per unit of additional concentrate expressed as kgDM/kg concentrate DM eaten, and changes in milk yield per kg extra feed DM eaten.**

References	I_h	I_c	I_t	S_r	I_A	Response (kg milk) per kg conc. DM eaten	Response (kg milk) per kg extra DM eaten
Present study							
'Cutting'	17.5	2.7	18.2	0.71	+0.26	+0.81	+3.14
'Cr2O3'	14.0	2.7	15.5	0.45	+0.56	+0.81	+1.47
Jennings and Holmes (1984)	12.6	4.0	16.5	0.03	+0.97	+0.52	+0.53
	12.6	4.0	16.2	0.13	+0.87	+0.67	+0.74
	12.0	5.0	16.4	0.15	+0.85	+0.42	+0.48
	12.0	5.0	15.7	0.32	+0.68	+0.48	+0.65
Arriga-Jordan and Holmes (1986)	18.1	6.0	21.2	0.36	+0.64	+0.52	+1.00
	15.3	6.0	19.4	0.13	+0.87	+0.50	+0.73
Stockdale and Trigg (1985)	8.0	1.8	9.9	0.00	+1.00	+1.60	+1.51
	10.6	1.8	10.7	0.94	+0.06	+1.20	0.00
	8.0	3.6	11.6	0.00	+1.00	+0.78	+0.78
	10.6	3.6	12.6	0.43	+0.57	+0.83	+1.45
	8.0	6.3	12.8	0.23	+0.77	+0.70	+0.92
	10.6	6.2	14.9	0.30	+0.70	+0.55	+0.82
Stakelum (1986a)	12.8	3.2	15.1	0.59	+0.41	+0.61	+0.85
	16.9	3.2	18.2	0.28	+0.72	+0.22	+0.54
Stakelum (1986b)	12.2	3.5	14.4	0.37	+0.63	+0.28	+0.47
Stakelum (1986c)	11.9	3.8	15.1	0.33	+0.67	+0.50	+1.38
Grainger (1987)	6.1	3.2	9.3	0.00	+1.00	+0.97	+0.97
(Grainger and	11.8	3.2	14.2	0.27	+0.73	+0.69	+0.92
Mathews, 1989).	15.9	3.2	16.9	0.69	+0.31	+0.31	+0.99

(Table 8.4.1 continued)

Suksombat (1988)	11.8	6.7	16.7	0.27	+0.76	+0.33	+0.45
	12.2	6.7	15.7	0.48	+0.56	+0.48	+0.92
Robinson and Rogers (1983)	10.8	3.6	14.3	0.03	+0.97	+0.50	+0.50
	14.5	3.5	16.9	0.31	+0.69	+0.03	+0.04
Rogers and Robinson (1983)	11.6	5.9	15.7	0.47	+0.69	+0.68	+0.98

I_h = Herbage DM intake by unsupplemented cows (kg/cow daily).
I_c = Concentrate DM intake by supplemented cows (kg/cow daily).
I_t = Total DM by supplemented cows (kg/cow daily).
S_r = Substitution rate (kgDM/kg concentrate DM consumed).
I_Δ = Changes in total DM intake (kgDM/kg concentrate DM consumed).

An animal's response to supplementary feeding has been shown to depend largely on the overall feeding level and on the initial herbage intake of unsupplemented cows (Leaver *et al.*, 1968; Bryant, 1978; Stockdale *et al.*, 1981; Bryant and Trigg, 1982; Stockdale and Trigg, 1985; Phillips and Leaver, 1985a,b; Stakelum, 1986a; Grainger, 1987). Grainger (1987), for example, reported the response in milk yield of 0.69 kg to 1 kgDM concentrate eaten where unsupplemented cows consumed an average 15.9 kgDM of herbage and the mean total DM intake of supplemented cows was 16.9 kg. At comparable herbage DM intake unsupplemented cows of 15.6 kg (cutting technique) and total DM intake of supplemented cows of 18.2 kg, the mean response in milk yield to concentrate supplementation in the present study was 0.82 kg milk/kgDM concentrate. However, when the responses are expressed in terms of kg milk/ kg extra DM eaten, the response in the present study is higher than that of Grainger (1987), representing 3.1 and 0.99 kg of milk per kg extra DM consumed respectively.

In addition to the increases in milk yield, yields of milk fat, milk protein and milk lactose in the present study were all increased by concentrate supplementation especially in Period I. The mean responses were 26 g milk fat, 26 g milk protein and 30 g milk lactose per kg concentrate DM eaten. The increased yields of these milk components by concentrate supplementation were due to increases in milk yield since concentrate supplementation had no effect on concentrations of milk composition.

In the present study the differences in milk yield between treatment groups still existed after 2 weeks without any concentrate feeding. However, the corresponding difference in yields of milk fat and milk protein had disappeared by this time (Table 8.3.7). The residual effect persisted in the present study probably due to the fact that the supplemented cows gained more weight and body condition score than the unsupplemented cows and probably mobilised energy deposition in the later stage. After the experimental period all cows were fed with the main herd with a decreased allowance, this change in plane of nutrition may also account for the disappearance of carryover effect.

8.4.2.2 Composition of Milk

The high protein (low protein degradability) concentrate supplementation had no significant effect on the concentrations of milk constituents in the present study (Table 8.3.8). Although some experiments have shown the effects on milk composition to be small (Leaver *et al.*, 1968), or to be absent (Johnson, 1977; Suksombat, 1988), many others have reported depressions in fat concentration with concentrate supplementation (Jennings and Holmes, 1984; Arriga-Jordan and Holmes, 1986; Stakelum, 1986a). The depression in milk fat concentration when concentrates were fed was probably due to an increase in supply of glucogenic precursors in the form of propionic acid and a decrease in supply of lipogenic precursors, namely acetic and butyric acids (Sutton, 1981), due to changes in rumen fermentation.

Although there were no significant effects of concentrate feeding on the concentrations of milk constituents, both a high allowance and concentrate feeding tended to cause small changes in the concentrations of milk fat and milk protein compared with the levels present prior to the start of supplementation (decreased fat from 4.74% to 4.28% for the PF cows and from 4.36% to 4.28% for the MF cows, increased milk protein concentration from 3.01% to 3.70% for the PF cows and from 3.03% to 3.68% for the MF cows, Table 8.3.8). The concentrations of milk lactose were also slightly increased in both groups.

The increased protein concentration was probably due to the increased supply of glucogenic precursors (propionic acids) when the cows were given a very high allowance and/or high protein concentrate. An increase in supply of propionic acid has been indicated to stimulate the synthesis of milk protein in the infusion studies, thereby causing an increase in protein concentration (Rook and Balch, 1961).

In New Zealand, Bryant (1980) also reported increases in concentration of milk protein (from 3.31 to 3.41%) with increasing level of feeding (increased herbage allowance from 26 to 40 kgDM/cow daily), however, further increases in herbage allowance to 50 kgDM/cow daily had no effect on concentration of milk protein. Similar observations have also been reported by Glassey *et al.* (1980) when herbage allowance was increased from 13.5 to 33.2 and 52.7 kgDM/cow daily with corresponding to increases in herbage intake from 9.6 to 14.3 and 16.3 kgDM/cow daily and milk protein concentration from 3.36 to 3.64 and 3.71%.

If the milk price also relies on milk protein concentration and hence milk protein yield, the feeding of very high allowance e.g. 50-60 kgDM/cow daily would give the greater milk protein than the present normal practice with feeding at a common allowance. However, the economic aspect should be taken into account before the decision was made. One promising method is that of adoption of the leader and follower grazing system where the high producing cows were fed at very high allowance and the low producing cows grazed after the high producing cows. Research to adopt such systems is needed and should compare in terms of economic return.

8.4.2.3 Liveweight and Condition Score

Although the final liveweight at the end of Period I between the MF and PF cows was not statistically significantly different, the MF cows tended to gain more weight and body condition score than the PF cows (Table 8.3.9). The supplemented cows (MF) gained on average 880 g/day liveweight and 0.18 unit body condition score more than the unsupplemented cows (PF).

The response in liveweight change due to supplementation in the present study was 326 g/kgDM concentrate eaten, which was higher than the response obtained in other studies averaging 106 g/day (Suksombat, 1988; Jennings and Holmes, 1984; Stockdale and Trigg, 1985).

8.4.3 POSSIBLE REASONS FOR DIFFERENCES BETWEEN TREATMENTS IN PERFORMANCE

It seemed likely from the above sections that a greater intake of ME could not completely explain the extra production (milk and liveweight gain) obtained by supplementation. The calculated supplies of RDP to both the PF and MF cows were similar whereas the supplies of UDP and ME to the MF cows were greater than to the PF cows (Table 8.3.10 and Table 8.3.11). When considered the ratios of RDP/ME both groups had higher ratios (ranging from 15.6 to 16.0 g/MJ) than the ratio of 8.1 g/MJ suggested by ARC (1984). This suggested that the supplies of RDP were more than enough to meet the nitrogen requirement of the rumen microorganisms. However, the possibility of a slightly higher supply of energy (in the rumen) from concentrate for the supplemented cows may have led to a higher production of microbial protein which should be available as a source of limiting amino acids or energy.

The higher milk yield produced by the supplemented cows could also be due to an increased supply of UDP (250-300 g/day; Table 8.3.12) from the high protein (low degradability) concentrate.

The ME available above maintenance estimated by cutting technique was 13 MJME/day higher in the supplemented cows than in the unsupplemented cows (Table 8.3.11). This should account for approximately 2.6 kg extra milk produced per day and was similar to the difference in milk measurement (2.2 kg/day) provided that no change in liveweight occurred. If a half of extra ME available above maintenance partitioned to milk and the other half to liveweight with no different change in liveweight, extra 6-7 MJME/day should account for only 1.2-1.4 kg of extra milk yield. In the present experiment the supplemented cows gained approximately 800 g/day more weight and 0.18 units condition score than the unsupplemented cows.

The differences in ME available above maintenance estimated by Cr_2O_3 method was 21 MJME/day higher in the supplemented cows. If a half of extra ME available above maintenance partitioned to milk and another half to liveweight provided that no difference in liveweight was measured due to short period of experiment, extra 10 MJME/day should account for 2 kg of extra milk yields which were similar to the measured difference in milk yield between the PF and the MF cows. Again there were differences in liveweight gain between the MF and PF cows.

If the performance parameters (milk yield, composition and liveweight gain) were measured accurately as discussed above, one possible reason to explain the higher differences in performance than which could have been expected from differences in ME available above maintenance is probably that the higher 250-300 gUDP/day in the supplemented cows whatever methods of measurement were applied would have improved the efficiency of ME utilisation above maintenance. This is supported by a slightly higher 'apparent efficiency' of use of ME for the MF cows than the PF cows (Table 8.3.11). Alternatively, the surplus supply of UDP over the requirement (Table 8.3.12) may have been used by animals as an energy source to produce the extra production.

However, it is interesting to note that the experimental period was short lasting for only two weeks (Period I). Measurements of unfasted liveweight and condition score are too variable. It is especially difficult to explain the responses observed, where the average apparent liveweight gain of 23 and 10.5 kg/cow over 14 days experimental period, representing 1.6 and 0.7 kg/cow daily and was associated with a gain of 0.26 and 0.08 units of condition score in the MF and PF cows respectively. The practice of measuring liveweight and condition score over such short periods of time in grazing experiments must be questioned.

Short term changes in DM intake and milk yield, and inaccurate estimates of short term liveweight changes probably account for some of the discrepancy between the estimated and the expected milk energy output.

If this is the case, the higher milk yield in the MF cows could be explained by the increased ME available without any effect of the protein in the concentrate.

8.5 CONCLUSION

1. A major contribution to extra milk yield from the supplemented cows in the present study was obviously due to the extra ME intake and hence extra ME available above maintenance.

2. The estimations of pasture intake by the cutting and Cr_2O_3 methods gave variable results, but in both cases the MF cows ate less pasture than the PF cows. The substitution rate varied between 0.4 and 0.7. Thus the ME intake were 12-22 MJ higher for the MF cows. The nature of the supplement was clearly favourable to total intake and apparently did not detrimentally affect normal rumen fermentation as judged by the high production response.
3. There was also a greater increase in production than could be accounted for by ME intake. That is the efficiency of use of ME above maintenance was higher for the MF cows. This may have been associated with the markedly higher intake of UDP by this group of cows.

CHAPTER 9

FEED PLANNING FOR SMALLHOLDER DAIRY FARM IN THAILAND

9.1 INTRODUCTION AND OBJECTIVES

Dairy production in Thailand has a significant potential for development because of its large population of some 65 million people and hence a large internal market. Today the dairy farmers of Thailand only supply 15.5% of total consumption with 84.5% coming from reconstituted milk powder imported from overseas. The present total dairy cattle population is 101,286 head with 44,450 cows in milk producing approximately 357 tonnes of raw milk/day (OAE, 1991). The national average milk production per cow is approximately 8 kg/day for 300 days lactation, but in the central areas where farmers have more experience, the average daily milk production per cow is as high as 10 to 12 kg.

The majority of Thai dairy farmers are smallholders, contributing 80% of the total milk volume, with an average herd size of 5-10 milking cows and an average effective area of 4 hectare. The present system of calving is on a monthly calving basis throughout the entire year. This inevitably forces the dairy farmers to rely heavily on expensive concentrates to maintain milk production particularly during the dry season. The cost of concentrates has been reported to be the biggest component (60%) of the 'on-farm' variable costs i.e. concentrate, fertiliser, animal health, labour and others (Pravee, 1987). A further problem, which is assuming increasing significance, is that of overstocking as many farmers are carrying too many young and replacement stock which together with the milking cows totals 5 to 6 animals per hectare. This can lead to serious overgrazing in the dry season when pasture growth is virtually zero (Figure 9.1).

Many regions of Thailand have a 6 to 7 months rainy period followed by a dry and often cool season (Figure 9.9) when growth of pasture forage is limited and often nil. Such periods of pasture shortage force farmers to use expensive concentrates as a means of feeding their cattle. However, farmers could reduce this expensive reliance on concentrates if they gave greater attention to improve and increase pasture productivity as shown by Lekchom *et al.* (1989). For those farmers with water available for irrigation there is also a significant potential for maintaining milk production from irrigated pasture or by the use of alternative, fast-growing forage crops such as maize and sorghum hybrids for that period. If water for irrigation is not available, then the farmers must conserve more pasture as silage during the periods of rapid growth in the rainy season.

Under the relatively high rainfall and high temperature of the tropics (Figure 9.9), the quantity of forage grown per unit area for livestock can be very high under adequate soil fertility. However forage quality tends to be relatively low and represents one of the major problems of the tropics. With in this 6 to 7 months rainy season, it is not difficult to produce 15,000 to 18,000 kg pasture dry matter per hectare with only medium inputs of fertiliser (Watkin, 1992), but the real problem is one of pasture management to ensure that the forage is utilised and controlled in order to maximise the quantity of green, leafy pasture of high quality. Furthermore, the surplus pasture produced during the rainy season can be conserved for feeding out during the dry period.

Since the natural forage supply comes in very discrete seasonal patterns and is not distributed evenly month by month (Figure 9.1), farmers must also consider the wisdom of their present system of calving cows throughout the year and examine the possibility of changing their calving pattern to seasonal calving. This would mean, calving most of the cows near the start of the rainy season i.e. the period of abundant fresh forage, and having them dry during the dry climatic period when forage is scarce and the animal requirement is for maintenance only (seasonal milk production).

The aim of this chapter is to provide an outline of feed planning throughout the year for smallholder dairy farms in Thailand i.e. try to match the feed supply with the feed requirement of the stock. The present report proposed two alternative feed plans, one for monthly calving throughout the entire year and the other for seasonal calving. Some assumptions were made to facilitate the interpretation of this report.

9.2 ASSUMPTIONS

1. In the present report, feed requirements have been calculated based on the ARC (1980, 1984). The metabolisable energy requirement was calculated and then expressed as kgDM of the feeds (MJME/(M/D)). Feed requirements were for a Friesian and Native crossbred cow weighing about 400 kg and producing about 3600 kg milk per lactation (OAE, 1991; DPO, 1991).

2. The total effective area of the farm was approximately average 4 ha (OAE, 1991).

3. Only the milking and dry cows (total of 15 cattle) were carried on the farm. The number of milking and dry cows, and daily milk production/cow in each month are presented in Table 9.2.1. Although the carrying capacity of Thai dairy farms varies widely, ranging from 2.5 to 5.5 animals/ha (Kanjanapruthipong *et al.*, 1990) the most common stocking rate would be around 3 to 4 animals/ha including milking cows, dry cows and young stock. For the typical Thai dairy farm of 4 ha this would represent a total of 12-16 animals. In this comparison only the milking and dry cows (15 animals) are carried on the farm with young stock being grazed elsewhere - as is the increasing practice of the better Thai farmers.

4. The grazing season was from 16th April to 15th November i.e. the rainy season. For the remainder of the year the animals were kept and fed in a penned area adjacent to the milking shed.

5. Feeding of concentrates to milking cows was considered to be 1 kg of concentrate per 3 kg of milk (Lekchom *et al.*, 1989) when pasture was a basal diet and 1 kg of concentrate per 2 kg of milk to correct for lower ME concentration of silage than pasture when silage was fed as a basal diet. Dry cows were fed concentrate at 1 kg daily.

6. Crude protein concentration and estimated ME concentration of the feeds are presented in Table 9.2.2 (obtained from experiments in Thailand; Chapter 4 and Chapter 5).

7. The daily pasture DM growth rates were obtained from a series of experiments carried out at the Dairy Farming Promotion Organisation of Thailand (DPO) during the 1988 and 1989 seasons (Hongyantarachai *et al.*, 1992; Witayanuparpyuenyong *et al.*, 1992; Sakpitaksakul *et al.*, 1992a,b). Although the recorded daily pasture growth in these references ranged from 60 to 100 kgDM/day, due to variations in pasture species used, in grazing intervals and in grazing efficiency, the average figure of 80 kgDM/ha daily reported by Hongyantarachai *et al.* (1992) was adopted and considered to fairly represent pasture growth rate throughout the rainy season.

8. Under grazing conditions, the utilisation of pasture grown was considered to be 70% i.e. 30% of growth was not eaten (Hongyantarachai *et al.*, 1992).

9. As with grazing, the harvesting losses plus storage losses of silage DM were also considered to be 30% (Skerman and Riveros, 1990).

Table 9.2.1 Number of milking and dry cows (head), and milk production (kg/cow daily) in each month for the two patterns of calving.

	Monthly Calving Pattern			Seasonal Calving Pattern		
	Milking Cows	Milk Yield	Dry Cows	Milking Cows	Milk Yield	Dry Cows
APR	13	12	2	15	12	0
MAY	13	12	2	15	14	0
JUN	13	12	2	15	16	0
JUL	13	12	2	15	15	0
AUG	13	12	2	15	13	0
SEP	12	12	3	15	12	0
OCT	12	12	3	15	11	0
NOV	12	12	3	15	10	0
DEC	12	12	3	15	9	0
JAN	12	12	3	15	7	0
FEB	12	12	3	0	0	15
MAR	13	12	2	0	0	15
Kg/cow		3650			3650	
Kg fat/cow		146			146	
Kg fat/ha		548			548	

Table 9.2.2 Average crude protein (%) and estimated ME concentration of the feeds (MJ/kgDM).

	Pasture	Silage	Concentrate*
Crude protein	12.0	-	17.0
	-	8.0	22.0
Estimated ME concentration	9.0	8.0	11.0

* Two concentrates: one with higher %CP fed with silage.

9.3 ANALYSIS OF FEED PLANS

9.3.1 FEED PLAN FOR MONTHLY CALVING PATTERN

Supplies and requirements of total feed and individual components of the feed per hectare, are presented in Table 9.3.1 and are illustrated in Figures 9.1 and 9.2. Total feed requirement by the milking and dry cows was 17.4 tonnes DM/ha annually whereas the pasture DM grown was 16.8 t/ha annually. It appears that if no supplement was purchased, there would be a deficit of approximately 0.6 tDM/ha of pasture DM to meet the requirement of the stock. If the losses for utilisation (approximately 30%) was taken into account, the pasture DM available was only 11.8 tDM/ha, increasing the deficit to 5.6 tDM/ha. In the present feed plan, however, 6.3 tDM/ha of balanced concentrate were fed to supplement the stock at various levels depending on the stage of lactation. Therefore, there would have been a surplus pasture DM of approximately 4.6 t/ha (11.8 tDM/ha of pasture available minus 7.2 tDM/ha of pasture intake) during the rainy season to be conserved as silage and then be fed out during the dry season. The calculated requirement of silage DM was 3.9 t/ha and this allowed approximately 16% for DM losses during feeding out (Skerman and Riveros, 1990; after losses due to harvesting and ensiling has been taken into account and were assumed to be 30%; See Section 9.2).

Table 9.3.1 Monthly calving: Daily pasture grown, total feed requirement and feed intake (Kg DM/ha), and total quantities for a 4 ha farm.

	KgDM/ha Daily					
	Total Pasture Grown	Net[1/] Pasture Utilised	Total Feed Required	Pasture Intake	Silage Intake	Concentrate Intake
APR (1)[2/]	0.0	0.0	51.1	0.0	29.3	21.8
APR (2)	80.0	56.0	46.1	31.5	0.0	14.6
MAY	80.0	56.0	46.1	31.5	0.0	14.6
JUN	80.0	56.0	46.5	31.9	0.0	14.6
JUL	80.0	56.0	46.5	31.9	0.0	14.6
AUG	80.0	56.0	46.5	31.9	0.0	14.6
SEP	80.0	56.0	45.7	31.1	0.0	14.6
OCT	80.0	56.0	45.7	31.1	0.0	14.6
NOV (1)[2/]	60.0	42.0	45.7	31.1	0.0	14.6
NOV (2)	0.0	0.0	50.3	0.0	28.5	21.8
DEC	0.0	0.0	49.9	0.0	28.1	21.8
JAN	0.0	0.0	49.9	0.0	28.1	21.8
FEB	0.0	0.0	49.9	0.0	28.1	21.8
MAR	0.0	0.0	51.1	0.0	29.3	21.8
TOTAL (tonnes/ha)	16.8	11.8	17.4	7.2	3.9	6.3
TOTAL QUANTITIES (tonnes)	67.2	47.2	69.6	28.9	15.5	25.2
SURPLUS PASTURE to be Conserved as Silage (tonnes)				18.3		

1/ = After 30% allowance was made for losses due to senescence.

2/ = Denotes 1st and 2nd halves of the month.

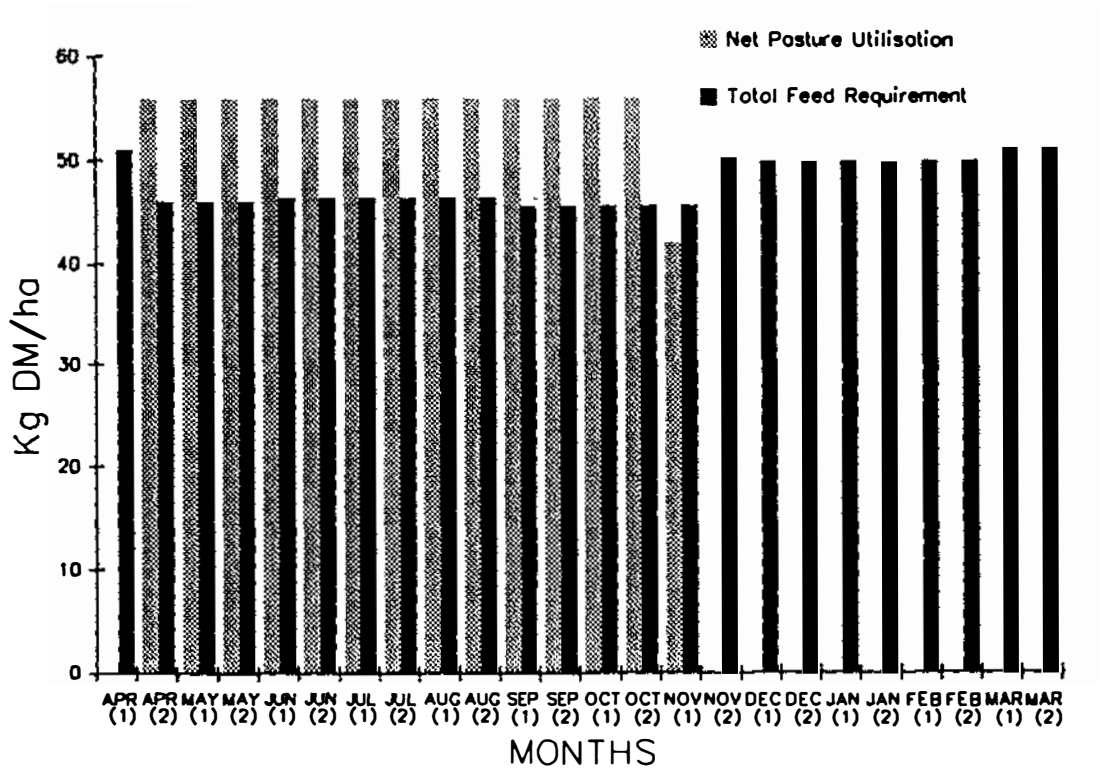

Figure 9.1 Monthly calving: Daily pasture grown and total feed requirement (kgDM/ha) [(1) and (2) indicate 1st and 2nd halves of the month respectively].

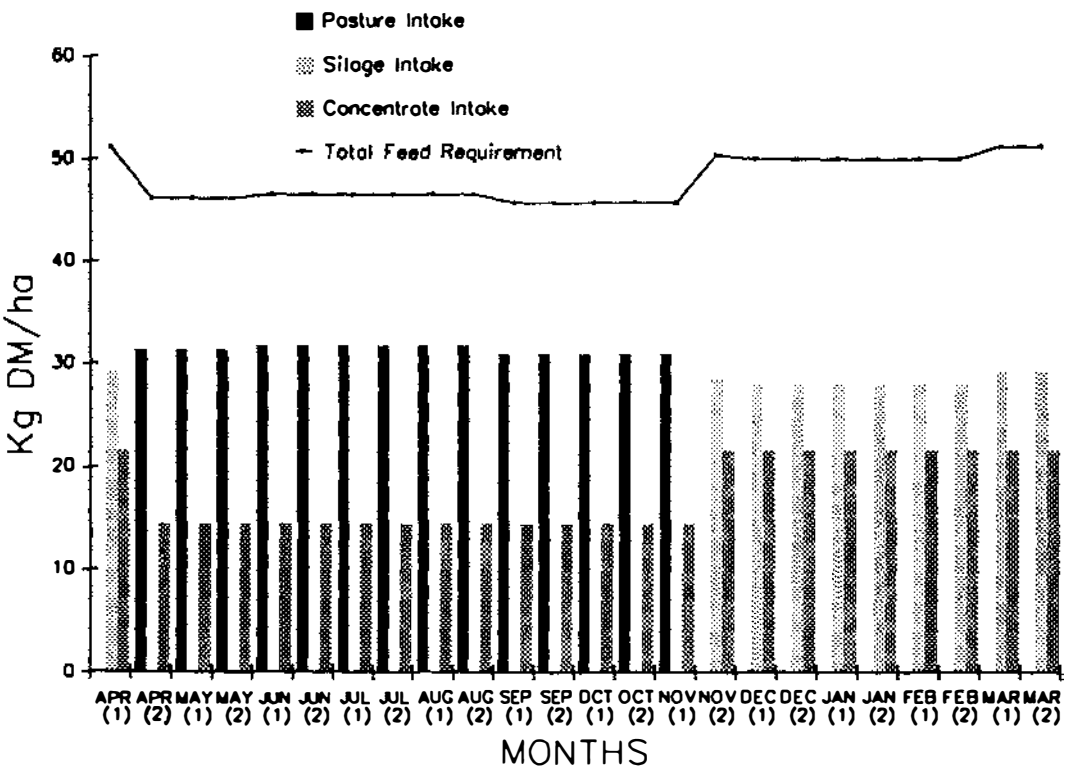

Figure 9.2 Monthly calving: Daily total feed requirement (solid line), and intakes of pasture, silage and concentrate (kgDM/ha) [(1) and (2) as in Figure 9.1].

The average daily feed supply and feed requirements (kgDM/cow) are presented in Table 9.3.2 and are illustrated in Figures 9.3 and 9.4. The total annual pasture DM grown per cow was 4.5 tonnes or 3.1 tonnes available when 30% allowance was made for losses due to utilisation, whereas the total annual feed DM requirement was 4.6 tonnes per cow. To overcome the deficit in pasture DM supply and to conserve pasture silage for dry season, approximately 1.7 tonnes of concentrate per cow (cost $NZ 560, at 33 cents NZ/kgDM) annually was fed to the cow. If concentrate was supplemented during the rainy season, there would have been approximately 1.2 tonnes pasture DM to be conserved as silage and the requirement of silage during the dry season was calculated to be approximately 1.0 tonnes per cow annually.

9.3.2 FEED PLAN FOR SEASONAL CALVING PATTERN

Supplies and requirements of total feed and individual components of the feed (per hectare) are presented in Table 9.3.3 and are illustrated in Figures 9.5 and 9.6. Total feed requirement by the stock was 16.3 tDM/ha annually whereas the pasture DM grown available was 11.8 t/ha annually. It appears that if no supplement was purchased, there would be a deficit of pasture DM to meet the requirement of the stock. In the present feed plan, however, 5.3 tDM/ha of balanced concentrate were bought to supplement to the stock. Therefore, there would have been a surplus pasture DM of 4.9 t/ha (11.8 tDM/ha pasture available minus 6.9 tDM/ha pasture intake) during the rainy season to be conserved as silage and then be fed out during the dry season. The calculated requirement of silage DM was 4.1 tonnes/ha and this allowed approximately 16% for DM losses during feeding out (Skerman and Riveros, 1990).

Table 9.3.2 Monthly calving: Daily pasture grown, total feed requirement and feed intake (Kg DM/cow).

	KgDM/cow Daily					
	Total Pasture Grown	Net[1/] Pasture Utilised	Total Feed Required	Pasture Intake	Silage Intake	Concentrate Intake
APR (1)[2/]	0.0	0.0	13.6	0.0	7.8	5.8
APR (2)	20.0	14.0	12.3	8.4	0.0	3.9
MAY	20.0	14.0	12.3	8.4	0.0	3.9
JUN	20.0	14.0	12.4	8.5	0.0	3.9
JUL	20.0	14.0	12.4	8.5	0.0	3.9
AUG	20.0	14.0	12.4	8.5	0.0	3.9
SEP	20.0	14.0	12.2	8.3	0.0	3.9
OCT	20.0	14.0	12.2	8.3	0.0	3.9
NOV (1)[2/]	15.0	10.5	12.2	8.3	0.0	3.9
NOV (2)	0.0	0.0	13.4	0.0	7.6	5.8
DEC	0.0	0.0	13.3	0.0	7.5	5.8
JAN	0.0	0.0	13.3	0.0	7.5	5.8
FEB	0.0	0.0	13.3	0.0	7.5	5.8
MAR	0.0	0.0	13.6	0.0	7.8	5.8
TOTAL (tonnes/cow)	4.5	3.1	4.6	1.9	1.0	1.7

1/, 2/ = As for Table 9.3.1.

Table 9.3.3 Seasonal calving: Daily pasture grown, total feed requirement and feed intake (Kg DM/ha), and total quantities for a 4 ha farm.

	KgDM/ha Daily					
	Total Pasture Grown	Net[1/] Pasture Utilised	Total Feed Required	Pasture Intake	Silage Intake	Concentrate Intake
APR (1)[2/]	0.0	0.0	50.3	0.0	27.8	22.5
APR (2)	80.0	56.0	46.9	31.9	0.0	15.0
MAY	80.0	56.0	51.0	34.1	0.0	16.9
JUN	80.0	56.0	53.3	33.4	0.0	19.9
JUL	80.0	56.0	51.4	32.6	0.0	18.8
AUG	80.0	56.0	47.7	31.9	0.0	15.8
SEP	80.0	56.0	45.7	31.5	0.0	14.2
OCT	80.0	56.0	44.3	30.4	0.0	13.9
NOV (1)[2/]	60.0	42.0	42.8	30.4	0.0	12.4
NOV (2)	0.0	0.0	44.2	0.0	25.5	18.7
DEC	0.0	0.0	42.8	0.0	25.9	16.9
JAN	0.0	0.0	42.0	0.0	27.0	15.0
FEB	0.0	0.0	31.8	0.0	28.1	3.7
MAR	0.0	0.0	33.7	0.0	30.0	3.7
TOTAL (tonnes/ha)	16.8	11.8	16.3	6.9	4.1	5.3
TOTAL QUANTITIES (tonnes)	67.2	47.2	65.3	27.5	16.5	21.1
SURPLUS PASTURE to be Conserved as Silage (tonnes)				19.7		

1/, 2/ = As for Table 9.3.1.

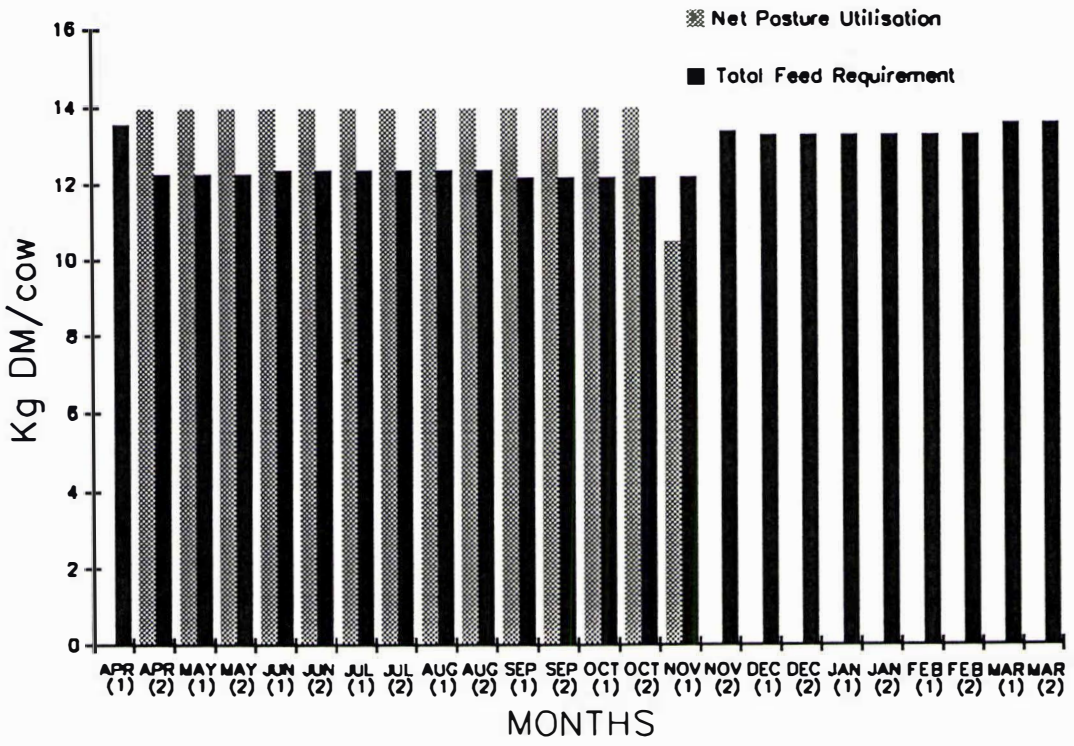

Figure 9.3 Monthly calving: Daily pasture grown and total feed requirement (kgDM/cow) [(1) and (2) as in Figure 9.1].

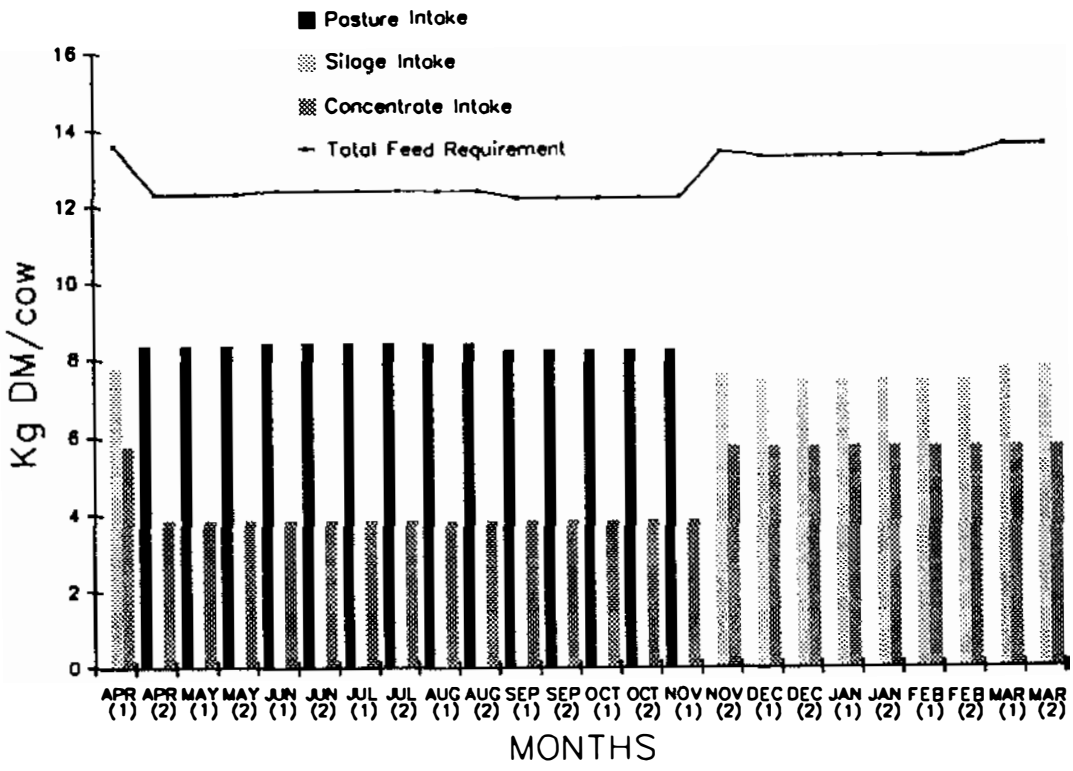

Figure 9.4 Monthly calving: Daily total feed requirement (solid line), and intakes of pasture, silage and concentrate (kgDM/cow) [(1) and (2) as in Figure 9.1].

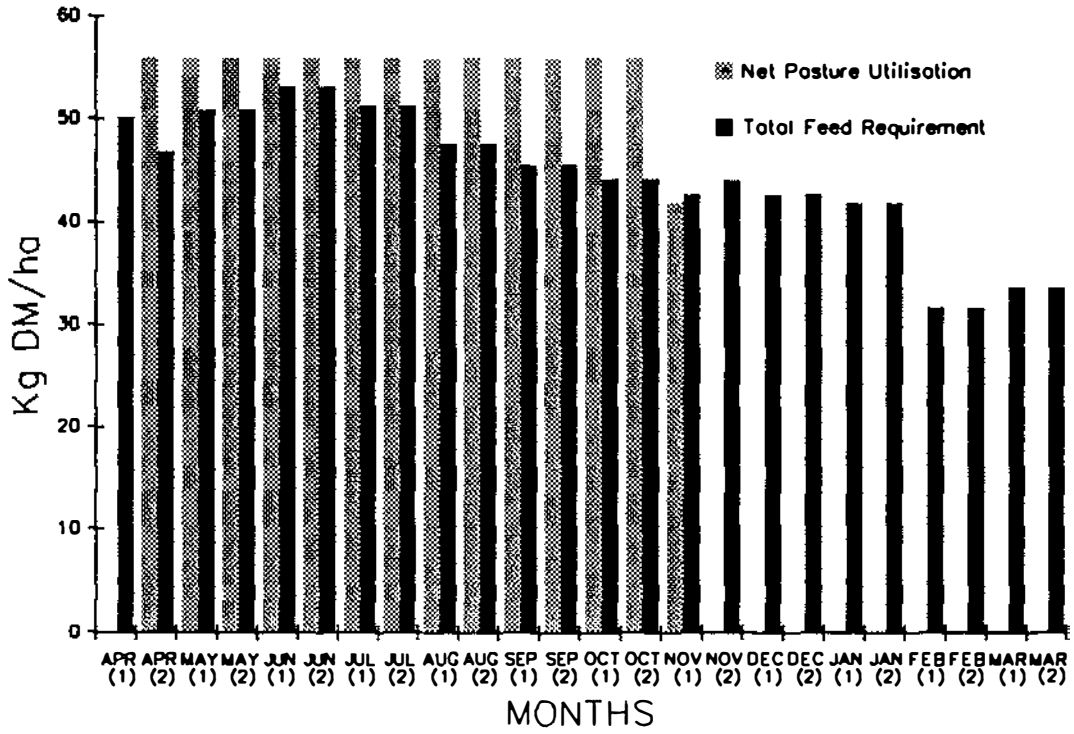

Figure 9.5 Seasonal calving: Daily pasture grown and total feed requirement (kgDM/ha) [(1) and (2) as in Figure 9.1].

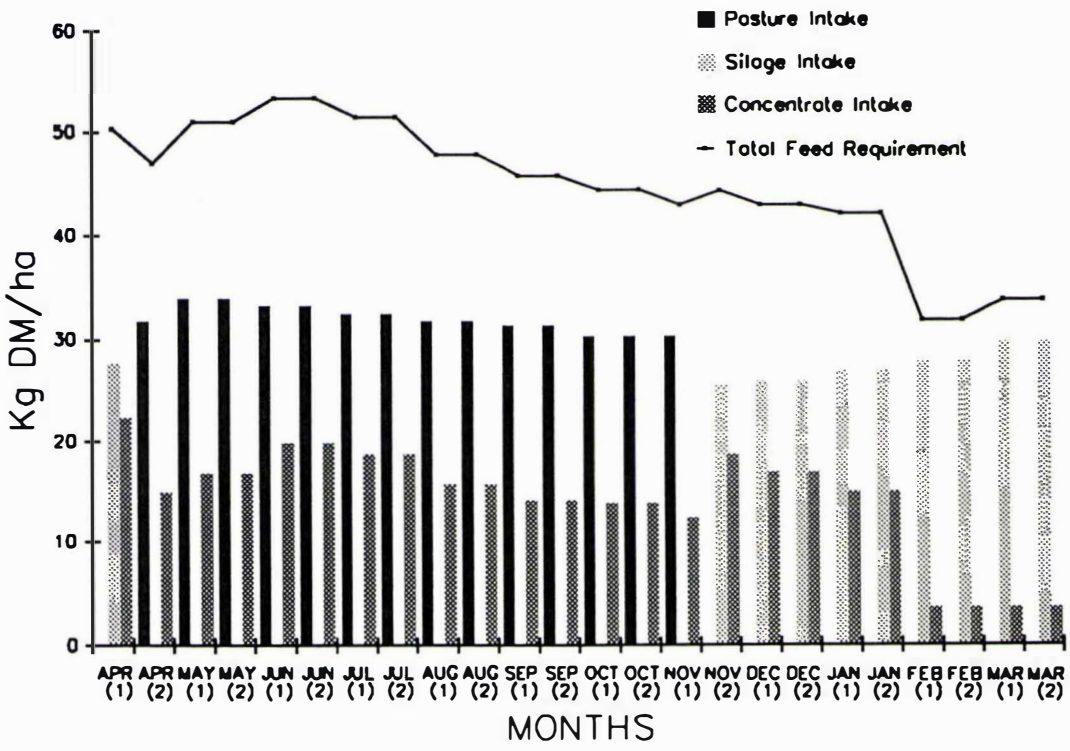

Figure 9.6 Seasonal calving: Daily total feed requirement (solid line), and intakes of pasture, silage and concentrate (kgDM/ha) [(1) and (2) as in Figure 9.1].

The average daily feed supply and feed requirements (kgDM/cow) are presented in Table 9.3.4 and are illustrated in Figures 9.7 and 9.8. The total annual pasture DM grown available per cow was 3.1 tonnes whereas the total annual feed DM requirement was 4.4 tonnes per cow. To overcome the deficit in pasture DM supply and to conserve pasture silage for dry season, approximately 1.4 tonnes of concentrate per cow (COST $NZ 462) annually was purchased as supplement. If concentrate was supplemented during rainy season, there would have been approximately 1.3 tonnes pasture DM to be conserved as silage and the requirement of silage during dry season was calculated to be approximately 1.1 tonnes per cow annually. This would allow 16% for DM losses during ensiling and feeding (Skerman and Riveros, 1990).

9.3.3 COMPARISON OF FEED PLANS

Comparisons of total feed requirement and feed eaten between monthly calving cows and seasonal calving cows are presented in Table 9.3.5. The data show that monthly calving cows required more total feed DM (0.2 tDM/cow) due mainly to the increased requirement for concentrate during the dry season when many of these cows were still milking at peak or near peak production than seasonal calving cows. Seasonal calving cows ate less pasture (0.1 tDM/cow) and concentrates (0.3 tDM/cow) but more silage (0.1 tDM/cow) than monthly calving cows.

Table 9.3.4 Seasonal calving: Daily pasture grown, total feed requirement and feed intake (Kg DM/cow).

	KgDM/cow Daily					
	Total Pasture Grown	Net[1/] Pasture Utilised	Total Feed Required	Pasture Intake	Silage Intake	Concentrate Intake
APR (1)[2/]	0.0	0.0	13.4	0.0	7.4	6.0
APR (2)	20.0	14.0	12.5	8.5	0.0	4.0
MAY	20.0	14.0	13.6	9.1	0.0	4.5
JUN	20.0	14.0	14.2	8.9	0.0	5.3
JUL	20.0	14.0	13.7	8.7	0.0	5.0
AUG	20.0	14.0	12.7	8.5	0.0	4.2
SEP	20.0	14.0	12.2	8.4	0.0	3.8
OCT	20.0	14.0	11.8	8.1	0.0	3.7
NOV (1)[2/]	15.0	10.5	11.4	8.1	0.0	3.3
NOV (2)	0.0	0.0	11.8	0.0	6.8	5.0
DEC	0.0	0.0	11.4	0.0	6.9	4.5
JAN	0.0	0.0	11.2	0.0	7.2	4.0
FEB	0.0	0.0	8.5	0.0	7.5	1.0[3/]
MAR	0.0	0.0	9.0	0.0	8.0	1.0[3/]
TOTAL (tonnes/cow)	4.5	3.1	4.4	1.8	1.1	1.4

1/, 2/ = As for Table 9.3.1.

3/ = All cows were dried off.

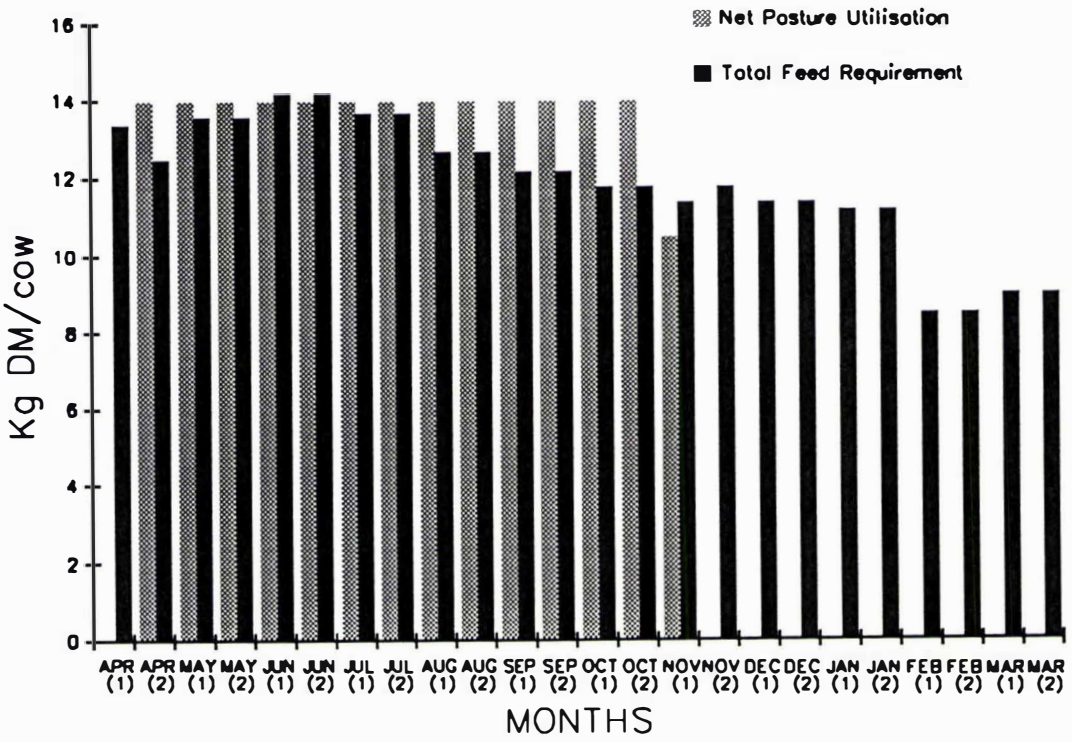

Figure 9.7 Seasonal calving: Daily pasture grown and total feed requirement (kgDM/cow) [(1) and (2) as in Figure 9.1].

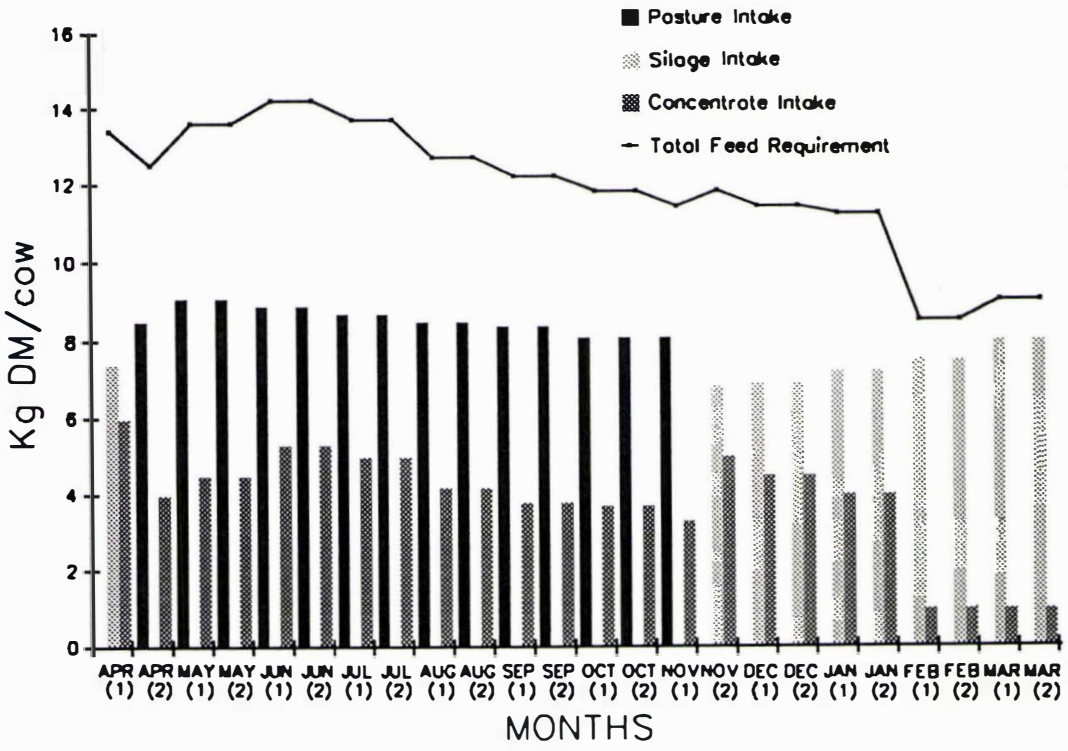

Figure 9.8 Seasonal calving: Daily total feed requirement (solid line), and intakes of pasture, silage and concentrate (kgDM/cow) [(1) and (2) as in Figure 9.1].

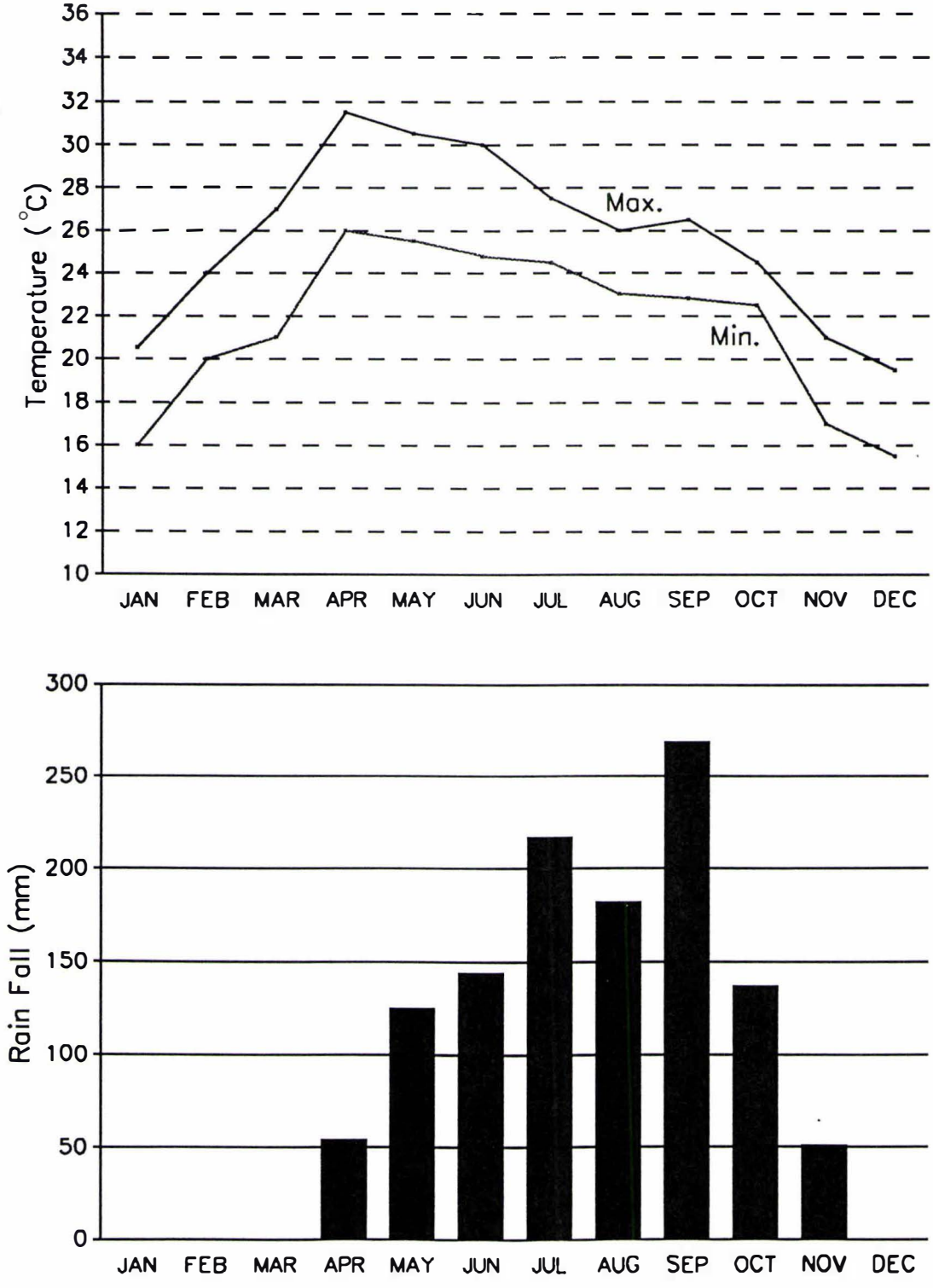

Figure 9.9 Average monthly maximum and minimum temperature, and rainfall in Thailand (avearge from 1986 to 1990; Meteorological Department).

Table 9.3.5 Comparison of feed required, feed eaten and cost of concentrate between monthly calving and seasonal calving feed plans.

	tDM/year	tDM/ha	tDM/cow	$NZ/cow
Total feed requirement				
Seasonal	65.3	16.3	4.4	
Monthly	69.6	17.4	4.6	
Pasture Intake				
Seasonal	27.5	6.9	1.8	
Monthly	28.9	7.2	1.9	
Silage Intake				
Seasonal	16.6	4.1	1.1	
Monthly	15.5	3.9	1.0	
Concentrate Intake				
Seasonal	21.1	5.3	1.4	462.0
Monthly	25.2	6.3	1.7	561.0

9.4 DISCUSSION AND CONCLUSION

The major advantage of the seasonal calving feed plan over the monthly calving feed plan is that it reduces the amount of concentrate required by 0.3 tDM/cow or 4.5 tDM/year which represents a significant saving to the farmers of $NZ 99/cow or $NZ 1485/year. Although this saving of approximately $NZ 1500 per year may appear small in the New Zealand farming context, to the small Thai dairy farmer this can meant a significant improvement in his standard of living because the average annual per capita income in Thailand is approximately $NZ 2,600 (Statistical Yearbook for Asia and the Pacific, 1991).

The seasonal calving feed plan also reduces the total feed requirement by 4.3 tDM/year. This is because the total requirement of monthly calving cows remains consistently high throughout the whole year while the total requirement of seasonal calving cows follows the normal cycle of milk production. During the dry season 12 to

13 monthly calving cows are still in milk and the average requirement of these cows is higher than the seasonal calving cows. Also during this period cows are fed on silage based diet which requires more concentrate to meet the required milk production. Thus the major contribution to the higher total feed requirement is from concentrate supplementation. The present system of monthly calving used by Thai dairy farmers can be successful only if a considerable amount of concentrate is supplemented.

Because of this worthwhile reduction in feed costs (approximately 18% of total concentrate cost) through seasonal calving, it is obvious that Thai dairy farmers should seriously consider the feasibility of changing the present system of monthly calving throughout the entire year to one of calving all or most of their cows at the start of rainy season i.e. seasonal calving. This would then ensure that the maximum animal demand, in terms of milk production, would coincide more closely with maximum pasture growth. It would also reduce the present problem that farmers face during the rainy season of trying to cope with and control the excess pasture growth with lower animal demands i.e. with fewer cows in milk. Invariably during this period of rapid growth pastures tend to get 'out-of-control' and the silage produced is commonly of low quality. Inevitably farmers are forced to rely heavily on expensive concentrate throughout the dry season plus poor quality silage which results in very expensive milk production.

The question is therefore, why do dairy farmers continue to persist with the present practice of monthly calving? Most of them merely reflect the practice of their fathers or neighbours. Some listen to the advise of Government advisers who claim, legitimately, that monthly calving spreads the labour demands more evenly throughout the year - but fail to point out the relatively high cost of concentrate feeding to cows in milk during the dry season. The guaranteed price paid to Thai dairy farmers is fixed by the Government and is not influenced by the world market price as occurs in New Zealand. Because it is a relatively high figure (55 cents NZ/kg milk, which is more than double the New Zealand farmers receive, and because the cost of living is considerably lower in Thailand compared with New Zealand, there is less pressure and urgency for farmers to increase their efficiency. Nevertheless the 'on-farm' costs of the Thai dairy farmers are rising at an increasing rate i.e. 33 cents NZ/kg milk present cost, as reported by Watkin (1992) and it is inevitable that these producers will be forced to examine and adopt more economic practices if they are to survive.

Some farmers are aware of the possible advantages of seasonal calving but are hesitant to change because of the possible difficulty in changing the reproductive cycle of their cows and the possibility of an associated loss in production. Certainly there would be a significant drop in total milk yield if farmers tried to change the calving date of all their cows in one year. However, if the process of adjustment was carried out gradually over a period of 3 to 4 seasons, it could be achieved with only a minor drop in milk production. For example, farmers should try to calve 40-50% of their cows in the first season to the seasonal pattern followed by another 20-30% in the second season and the rest in the third and possibly fourth season. In doing this, the associated reductions in the need for and use of dry-season concentrate would gradually reduce costs.

Some farmers express doubts concerning the ability of the adjusted cows to become pregnant. In fact it is more likely that the cows inseminated or mated in the June/July period, when pasture is abundant and cows are in good condition, will have a higher conception rate than cows inseminated during the dry season. All farmers know that conception is no problem if the cow is well fed and in healthy condition. This is more likely to occur in June/July than in December/January when green forage is nil and farmers are forced to spend heavily on concentrate and commonly inclined to limit the amount in an endeavour to reduce costs and so underfeed their animals. Although ambient temperatures are higher in June/July than in December/January, the levels experienced during June/July of approximately 25-30°C should not have any detrimental effect on conception. For example in Israel, where cows during summer (21-34°C) and during winter (10-19°C) were compared, reported that rectal temperature were 39.7 and 38.9°C for summer and winter cows respectively. Mean intervals from parturition to conception ('open days') were 91 and 87 days for summer and winter cows respectively. Although the summer cows had slightly lower conception rate (50 vs 72%) than the winter cows, the difference was not statistically significant different (Folman *et al.*, 1979).

It is also relevant to point out that under seasonal calving, farmers have that essential opportunity to repair, to overhaul, to upgrade and generally maintain the many items of equipment in good condition - i.e. their milking machines, farm machinery or fence - during the 'off-season', which is extremely difficult to achieve under the constant demands of the monthly calving system.

Some authorities express concern about the effect of seasonal calving on milk handling and processing. It is believed that the sharp increase in the volume of milk arriving at the dairy plant in May/June/July, followed by a gradual decline to minimal quantities in February/March/April would cause serious plant management and operating problems. However, one real advantage of seasonal milk production to dairy factory managers is the opportunity it provides to carry out effective machinery maintenance and organise annual staff holidays. For example, during the low-supply months it would be possible for processors to close down some of the machines to enable a thorough machinery overhaul and maintenance to be undertaken and also allow a significant percentage of staff to take their entitled annual holiday with minimum labour disturbance. From the comments of the local factory managers, it is extremely difficult under the present system of constant monthly input, to find time for those essential repair and maintenance jobs, which often leads to overloading of machines, inadequate maintenance, and hence frequent breakdowns and higher operating costs. These could be reduced significantly under a seasonal operating system.

One reason given by some farmers in favour of retaining the present monthly calving system relates to the financial demands involved. The farmer is normally required to make his capital and interest repayments monthly to the bankers and hence must have his regular monthly milk cheque from the dairy company to meet these demands. Obviously this is important to the farmer but the lending institutions would probably be willing to reconsider the system of repayment as, first and foremost, they are keen to see dairy farmers succeed, and make a healthy profit and so repay their loans as quickly as possible.

It is probable that if the advantages of the seasonal calving system were fully explained to the bankers they would be willing to adjust the repayment system to meet the changed situation.

The change to seasonal calving will also affect the sales of milk and milk products. However, fortunately most of the raw milk produced is processed into UHT milk and therefore can be stored for several months without deterioration. Pasteurised milk, the other important product, cannot be stored and its supply would of course detrimentally affected. Therefore it will be necessary to give particular attention to this product and it may well require the introduction of a financial incentive to farmers to encourage some

farmers to produce 'dry-season' milk for processing into pasteurised milk. As raw milk production, in Thailand only meets 15.5% of demand and hence reconstituted milk 84.5%, it will be necessary, under seasonal milk production, to adjust the proportion of reconstituted milk being fed into the market throughout the year in order to protect the local producer of raw milk. Obviously these matters will have to be examined and discussed fully in order to find the most satisfactory solution.

In contrast to Thai dairy industry, other milk producing countries such as New Zealand and countries in Europe, the large volume of raw milk produced during the early grazing season can be processed into milk powder and other milk products i.e. butter and cheese and then exported to other countries.

CHAPTER 10

GENERAL SUMMARY AND OVERALL DISCUSSION

10 GENERAL SUMMARY AND OVERALL DISCUSSION

The objectives of the present study were to measure the effects of supplementation with concentrates which differed in their protein concentrations and protein degradabilities on the performance of dairy cows, with emphasis on tropical feeds.

The results of each experiment have been discussed in detail in Chapters 4, 5, 7 and 8. The aim of this chapter is to present a brief overview of all results and some general conclusions, to make brief comparisons with the most relevant published works, to suggest areas for further research and finally to relate the relevance of results obtained in this study to dairy farming in Thailand.

10.1 RESUME OF RESULTS AND CONCLUSION

10.1.1 EXPERIMENTS WITH DAIRY COWS IN THAILAND

In Chapter 4, the cut forages in the indoor experiment were low in crude protein concentration (12% CP) and in digestibility (61% DMD) whereas crude protein concentration (13% CP) and digestibility (63% DMD) in the herbage of the grazing experiment were slightly higher. These levels are within the range of 3 to 15% CP (mean 11% CP) and 30 to 75% DMD (mean 54%) reported by Minson and McLeod (1970), and much lower than the levels of crude protein and digestibility that Minson (1989) reported in temperate pastures (18% CP and 71% DMD), or measured in the experiment conducted in New Zealand (22% CP, 78% DMD; Chapter 8).

In both the indoor and grazing experiments there was general agreement in that concentrate supplementation reduced forage DM intake in both studies (mean 0.40 kgDM/kg concentrate DM eaten). Furthermore as the level of concentrate supplementation increased so also did the substitution of concentrate for pasture (from 0.20 at 2.7 kgDM concentrate to 0.45 at 5.4 kgDM concentrate). However the extent of this reduction in forage intake was variable, probably because of the confounding effect of the concentration of protein and protein degradability, and the level of concentrate feeding.

Many authors have reported a reduction in basal forage intake when concentrates are fed to dairy cows (Combellas *et al.*, 1979) but the effect of level of concentrate feeding on substitution rate has been shown to be variable both in temperate (Stockdale and Trigg., 1985) and tropical (Combellas *et al.*, 1979) studies. With concentrate supplementation to temperate grass silage fed cows, Clements *et al.* (1989) reported substitution rate was 0.07 kg silage DM/kg concentrate DM intake with 30% CP concentrate and was 0.22 kg silage DM/kg concentrate DM intake with 18% CP concentrate. This suggested that high crude protein concentration reduced substitution rate through improved silage DM intake.

Meijs (1981) however reported a consistent increase in substitution rate with increasing levels of concentrate from his comprehensive review of 11 indoor feeding experiments with temperate pasture.

Concentrate supplementation increased the yield of milk and liveweight gain in both the indoor and grazing experiments. The response in milk yield to concentrate ranged from 1.2 to 2.0 kg milk/kg concentrate DM eaten. These responses were higher than those reported in the tropics being 0.6 kg milk/kg concentrate DM eaten (Jennings and Holmes, 1985) and in the temperate region being 0.4 kg milk/ kg concentrate DM eaten (Leaver *et al.*, 1968; Journet and Demarquilly, 1979). The higher response obtained in the present study is probably due to the poorer quality of pasture compared with those fed in the literature quoted and the consequent low intake of pasture and low milk yield by cows on pasture alone. When low quality forages such as those used in the present study are fed to the dairy cows, apart from the effect of low total intake of energy and protein from pasture, there will be a deficit of nutrients such as nitrogen and carbohydrate to enhance microbial activity in the rumen which supply substrates required for milk production. Supplementation with concentrates containing such nutrients would produced a greater response than when supplemented with high quality roughages.

With regard to the level of concentrate supplementation, increases in level of concentrate reduced the response (kg milk or g liveweight/kg concentrate DM eaten) in milk yield and liveweight gain in both the indoors and under grazing experiments (e.g. from approximately 2.0 to 1.2 kg milk when amount of concentrate DM eaten increased from 2.7 to 5.4 kg). The responses in milk yield to concentrate

supplementation have also been consistently reported to decline as the concentrate level increases in the tropics (Combellas *et al.*, 1979) and in the temperate regions (Stockdale and Trigg, 1985).

With regard to the composition of concentrate (i.e. protein concentration and degradability), the high protein (low degradable) concentrate tended to give higher responses in milk yield and liveweight gain per kg concentrate DM eaten. Supplementation with proteins that are resistant to degradation (e.g. formaldehyde treated casein) in the rumen have been reported to increased milk yield of dairy cows (Stobbs *et al.*, 1977; Flores *et al.*, 1979). These latter trials also reported a high response of 2.0 to 2.4 kg milk/kg supplement.

In Chapter 5, the silage fed to the dairy cows, made from tropical pasture of 8 to 10 weeks regrowth, was very low in crude protein concentration (5%) and dry matter digestibility (48%), probably due to the overmaturity of the pasture cut and the losses of soluble carbohydrate and protein during ensiling. The low crude protein and low digestibility of silage was probably due to the low quality of the original pasture. In addition, tropical grasses are well known for their stemminess, and hence their high crude fibre and low soluble carbohydrate levels. A combination of these factors results in a delayed fermentation and proliferation of costridial organisms in the ensiling process. The delayed fermentation and proliferation of clostridium leads to greater production of butyric acid, an increase in protein degradation and an increase in effluent losses (Miller, 1969; Catchpoole and Henzell, 1971; Holm, 1974) and hence results in a silage of low crude protein and DM digestibility which may have occurred in the present studies.

The experiment with silage fed as a basal diet was designed to determine the effect of protein degradability in the concentrate on silage DM intake. The results showed that cows on Concentrate 2 (0.63 dg, 1% urea) and on Concentrate 1 (0.57 dg, no urea) ate similar quantities of silage DM, but more than was eaten by the cows on Concentrate 3 (0.68 dg, 2% urea) and on Concentrate 4 (0.62 dg, no urea).

Cows on Concentrate 2 produced larger yields of milk and milk protein, and liveweight gain than cows on the other concentrates. The major cause of this higher production was probably the higher ME intake from the increased silage DM intake and the higher UDP intake from the Concentrate 2.

In the temperate regions, from a review of 13 feeding experiments involving comparisons between diets of differing UDP content, Twigge and Van Gils (1984) concluded that the effects of increased UDP supply on milk yield were variable, responses ranging from -0.6 kg milk/day to +2.9 kg milk/day between experiments. The authors pointed out that a variety of factors contributed to this variability. One experiment where dairy cows fed on silage based diets were supplemented with a mixture of fishmeal and soyabean meal, and cereal concentrate, Rae *et al* (1986) reported substitution rates for cereal concentrate and fishmeal-soyabean mixture of 0.23 and -0.52 kgDM silage/kg concentrate DM eaten respectively. The responses in milk yield were 1.3 and 3.5 kg/kg concentrate DM eaten.

In recent years, the experiments with silage based diets where the dietary protein from the concentrates have been modified either simply through addition of low rumen degradable animal protein sources containing fishmeal or through inclusion of fishmeal in the diet in replacement for soyabean meal, cows have shown substantial increases in milk yield (Girdler *et al.* 1987). Corresponding results with fish meal have also been reported by Kassem *et al.* (1987). It is worth noting that in these experiments the increased milk yield was accompanied by an increased intake of silage. The exact mechanism is unclear, e.g. the ruminally-degradable protein may have increased rumen microbial efficiencies (Rooke *et al.*, 1983; Rooke *et al.*, 1985) resulting in a greater flow of microbial protein to the duodenum or, alternatively, the milk yield response may have been elicited by the UDP. It is unclear whether the fishmeal responses could be attributed to changes in UDP supply or to the amino acid composition of the UDP.

10.1.2 EXPERIMENT ON RUMEN METABOLISM

In this experiment (carried out in New Zealand), low quality hay was used to simulate tropical roughages. The concentration of crude protein in the hay (8%) was in between those obtained from silage and pastures used in Thailand's experiments. The digestibility of hay DM (50% DMD) was however lower than those in tropical pastures (61% DMD) but slightly higher than that of silage (45% DMD).

Although there were no major favourable effects (high level of rumen ammonia maintained over the day, increased digestibility and hence intake of hay DM) caused by the inclusion of urea in the concentrates in the present study, the temperature had a marked effect on the parameters measured. The interpretation of the results of the effects of urea may have been masked by the dominant effect of temperature. The hot temperatures reduced hay DM intake, increased concentrate:hay ratio, and consequently tended to reduce rumen pH and this may have altered the rumen environment and microorganism population. At low rumen pH (below 6) greater absorption of ammonia (particularly in the early hours after concentrate feeding) through the rumen than at high pH (7) has been reported (Leng and Nolan, 1984). The present experiment did not measure the rumen ammonia concentration until 3 hours after concentrate feeding, therefore, this aspect can not be discussed.

In the present experiment the concentrate was fed only twice daily which may have caused a brief increase in the supply of ammonia for a short period (soon after concentrate feeding). The low concentration of ammonia (120-130 mgNH_3-N/litre) for most of the day may have reduced fibre digestion and hence reduced the intake of hay DM.

Animals in the tropics are subject to hot environmental temperatures which have a marked effect on intake of the feed (Chapter 7). In addition, the tropical forages are usually low in nutritive value (low nitrogen content and low digestibility) as mentioned earlier in this section and in the previous Chapters (Chapter 4 and Chapter 5). These two factors contribute to the low production of animals in the tropics. Supplementation of concentrate usually reduced forage DM intake (Chapter 4). The possible feeding managements are to increase the frequency of feeding concentrate to ensure that high level of rumen ammonia are continuously supplied in the rumen or to include slowly degradable protein (bypass protein) in the concentrate. An alternative approach is the use of urea molasses block to maintain a higher concentration of ammonia in the rumen as previously discussed in Chapter 7.

10.1.3 EXPERIMENT WITH DAIRY COWS IN NEW ZEALAND

In Chapter 8, the pastures used in this grazing experiment were higher in crude protein concentration (22%) and digestibility (78%) than those pastures and silage used in the previous experiments in Thailand (Chapter 4 and Chapter 5) and than those reported by Minson (1989) for temperate pastures.

Supplementation of concentrate in the present study also reduced pasture intake by 0.71 kgDM/kg concentrate DM eaten. This value was higher than obtained in the previous studies (Chapter 4) and than 0.55 kgOM/kg concentrate OM eaten reported by Leaver *et al.* (1969) in the temperate regions. However a very high allowance was offered in the present experiment, and the corresponding substitution rates reported by Meijs and Hoekstra (1984) and Grainger (1987) were 0.70 - similar to the present value.

The relatively low substitution rate measured with tropical pastures was probably also due to the fact that the tropical pastures are low in nitrogen content and digestibility, so that supplementation with concentrate containing fermentable nitrogen may have increased fibre digestion and forage intake (Orskov *et al.*, 1972) and consequently caused a smaller substitution rate. Meijs (1981) also suggested that the substitution rate was low when concentrate was supplemented to low quality (0.50-0.65% DM digestibility) roughage, for similar reasons.

Concentrate supplementation also increased yield of milk by 0.8 kg/kg concentrate DM eaten in the present study. This value was higher than 0.4 kg milk/kg concentrate DM eaten reported by Leaver *et al.* (1968), and Journet and Demarquilly (1979) but much lower than obtained from the previous studies (Chapter 4). The poorer quality of tropical pastures compared with temperate pastures may explain this difference. Tropical pastures fed as a sole diet can only support low milk yields in dairy cows because their inability to supply enough protein and glucogenic energy (Preston and Leng, 1987). If concentrates containing fermentable nitrogen and carbohydrates are fed, the response by the supplemented cows may be larger than would be predicted from the increased energy intake. Another reason is that in the temperate experiment, a very high allowance was given to the cows, and high substitution rate was measured.

10.2 PRACTICAL IMPLICATION FOR THAI DAIRY FARMERS

In the feeding experiment conducted in Thailand, the major cause of higher production (milk plus liveweight) in the supplemented cows was increased ME intake, particularly from concentrate. Increases in the intake of concentrate caused increases in milk production due to the increased ME intake. Because of the effect of substitution, increases in total ME intake (from pasture plus concentrate) are smaller than the increased ME supplied by the concentrates.

The effect of increased crude protein concentration in the concentrate on forage DM intake and on milk yield was variable. Concentrate supplementation was given twice daily and, as suggested by the results of the sheep experiment (Chapter 7), the rumen ammonia concentration probably increased only briefly after feeding and then declined to low levels. Such conditions may not encourage increases in fibre digestion and microbial activity. Increases in frequency of feeding and thus the provision of high rumen ammonia concentration over the whole day may promote microbial activity and digestion of fibre and lead to increases in intake of forage and milk yield (Preston and Leng, 1987).

The effect of low protein degradability of concentrate on forage intake and milk yield was also variable in Chapter 4 (cows fed on fresh pasture) but inclusion of low degradable protein did appear to cause increased milk yield and increased silage intake in Chapter 5 (cows fed on low quality tropical grass silage). The low degradable protein feedstuffs may vary in their composition and degradability. Those experiments that have obtained positive responses to low degradable protein often involved the infusion of casein (Clark, 1975) or supplementation of protected casein or fishmeal (Orskov *et al.*, 1977). In contrast, the present study obtained low protein degradability of concentrate mainly by inclusion of cotton seed meal. The feedstuffs obtained from industrial byproducts may vary greatly in their composition and protein degradability depending on the processes applied (Lindberg, 1985), although the results reported in Chapter 6 showed that cotton seed meal did have a low protein degradability.

The very low calculated apparent efficiency for the use of ME above maintenance in the tropical experiments can be attributed to two possible errors;- firstly, an overestimation of ME concentration in tropical forage (by using the equation obtained from temperate experiments and using *in vitro* digestibility) and secondly, the underestimation of ME requirement for maintenance by animals in the tropics. The higher temperatures in the tropics relative to the temperate regions may increase the requirement of ME for maintenance (Blaxter, 1967).

However, there are limitations to the interpretation of the present results (particularly Chapter 4 and Chapter 5) due to the confounding of differences in the degradability of protein in the concentrate, and differences in crude protein concentration, (also the balance of protein sources, type of starch, amino acid content and inclusion of urea and molasses). Future experiments should be designed so that such confounding effects are avoided. For example, if the purpose of the experiment is to examine effects of protein degradability on cow performance, a single source of protein should be used, with its degradability varied by heat or chemical treatments.

The results of the present study can supply some information to Thai dairy farmers and the following recommendations can be made from the research.

In the present study, yield of milk was increased by concentrate supplementation. At present costs and prices the increases in level of concentrate supplementation gave a profitable marginal return. Although the high protein (low degradable) concentrate gave slightly larger marginal return in yield, the concentrate with low protein concentration was cheaper than the concentrate with high protein concentration and gave the greater financial benefit. The cost of the extra protein (with low degradability) was larger than the value of the extra milk obtained.

When dairy cows are fed on a silage based diet, the concentrate containing low degradable protein improved silage DM intake and hence milk yield. Thus the Thai dairy farmers can rely on feeding their cows with improved pasture and moderate level of low protein concentration concentrate. During the dry season when cows are fed on grass silage, it may be worthwhile to supplement with a concentrate containing a protein of low degradability (e.g. Concentrate 2).

The economic assessments made in Chapter 4 showed that supplementation with a moderate level (i.e. 5.4 kgDM/cow daily) of low crude protein (17% CP) concentrate to dairy cows fed on fresh pasture gave the best marginal financial return. Supplementation with concentrate containing approximately 84 gUDP/kgDM (Concentrate 2 in Chapter 5), fed at 4.5 kgDM/cow daily, gave the best financial return for cows on tropical grass silage.

10 .3 AREAS FOR FUTURE RESEARCH

One of the major needs is to measure the nutritive value of individual feedstuffs when given as supplements to dairy cows fed tropical roughage. This can be obtained by supplementing individual feedstuffs such as cotton seed meal, maize or soyabean meal to dairy cows at moderate level (i.e. 4 kgDM/cow daily) and measuring the response in animal performance to such individual feedstuffs. A further investigation can be carried out on the effect of level (i.e. 2-3 levels) of the selected individual feedstuffs (2-3 feedstuffs) on dairy cow performance. Economic analyses can then be carried out.

The results obtained in the above experiments can then be applied by formulating the appropriate concentrate using selected feedstuffs which are of known nutritive value and protein degradability from the previous experiments including the values reported in Chapter 6. These concentrates could be formulated to supply certain proportion of RDP and UDP (i.e. within the range used in Chapter 5; for example, 65:35, 60:40 and 55:45 or expressed in terms of gRDP/gUDP; 136:74, 126:84 and 116:94 per kg concentrate DM). The resultant concentrates could then be tested by feeding trials with dairy cows. This field of research is most likely to make significant contributions to the improvement of dairy cow nutrition in Thailand.

In order to ensure a continuous supply of high rumen fermentable nitrogen (rumen ammonia concentration), increases in frequency of feeding may be useful. This possibility must be tested by experimental research. For example, the effects of increased feeding frequency (from the normal practice of twice daily, to 3, 4 or 6 times daily) on the productivity of cows should be researched. However, this must be considered in terms of economics (i.e. labour cost) and can only be applied to the Thai smallholder dairy farmers.

There is also a need for work on the use of a urea-molasses multinutrient block (i.e. 10% urea, 30% molasses, 20% rice bran, 30% cotton seed meal plus sulphur and other minerals) that is suggested to provide a continuous supply of fermentable nitrogen and carbohydrate, bypass protein and minerals. However, the erratic behaviour of cows in using such supplements should also be considered.

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APPENDICES

1 METEOROLOGICAL DATA FOR EACH MONTH FROM APRIL 1990 TO DECEMBER 1992

1.1 METEOROLOGICAL DATA FOR CHAPTER 4 (MUAKLEK, THAILAND)

Details of daily maximum and minimum temperature (°C), relative humidity (%) and rainfall (mm) between October 1st and December 31st 1990 are illustrated in Figure A.1.

1.2 METEOROLOGICAL DATA FOR CHAPTER 5 (MUAKLEK, THAILAND)

Details of daily maximum and minimum temperature (°C), relative humidity (%) and rainfall (mm) between January 1st and March 31st 1991 are illustrated in Figure A.2.

1.3 METEOROLOGICAL DATA FOR CHAPTER 8 (PALMERSTON NORTH, NEW ZEALAND)

Details of daily maximum and minimum temperature (°C), relative humidity (%) and rainfall (mm) between June 1st and 30th 1990 are illustrated in Figure A.3.

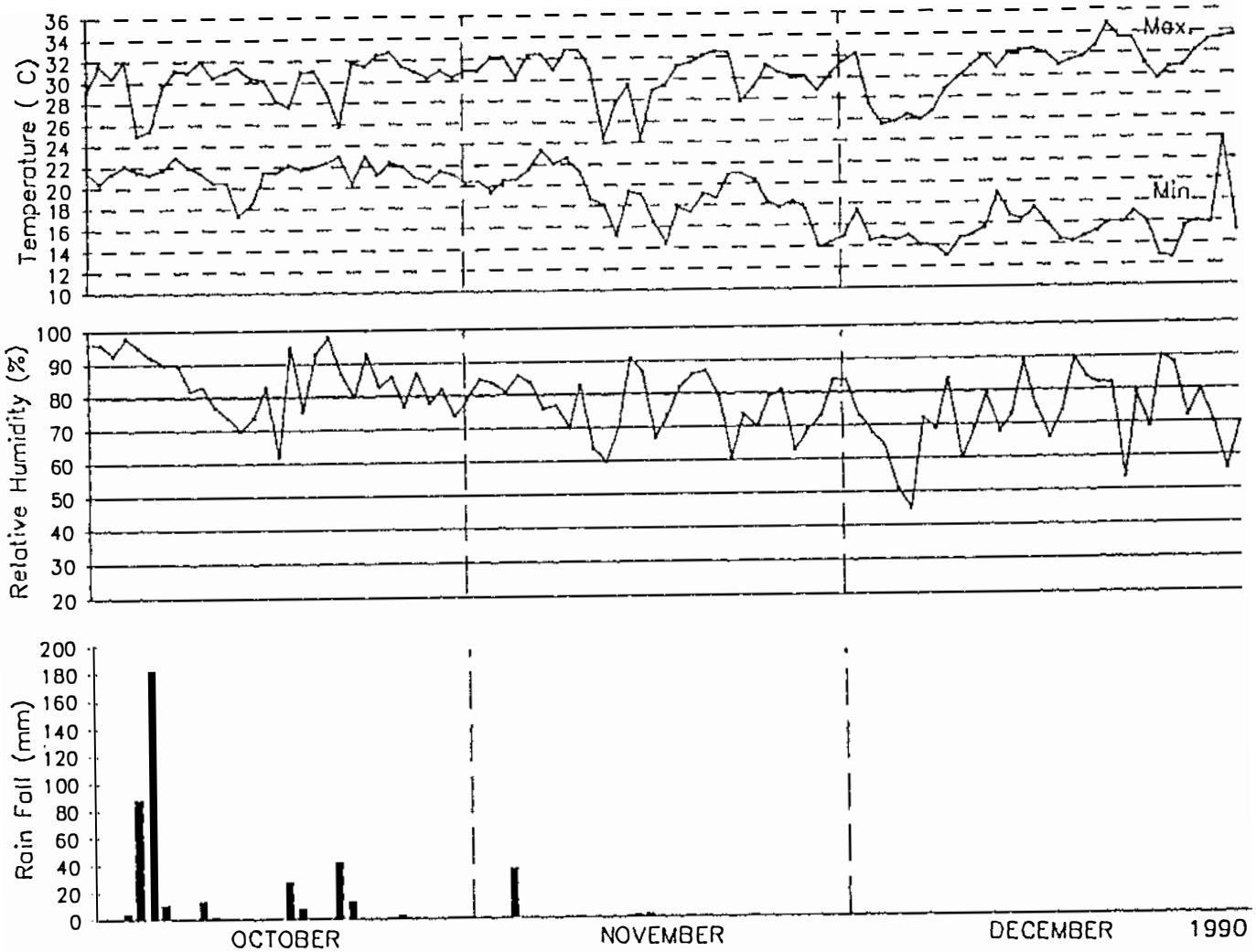

Figure A.1 Daily maximum and minimum temperature (°C), relative humidity (%) and rainfall (mm) in Thailand during October-December 1990 (Chapter 4).

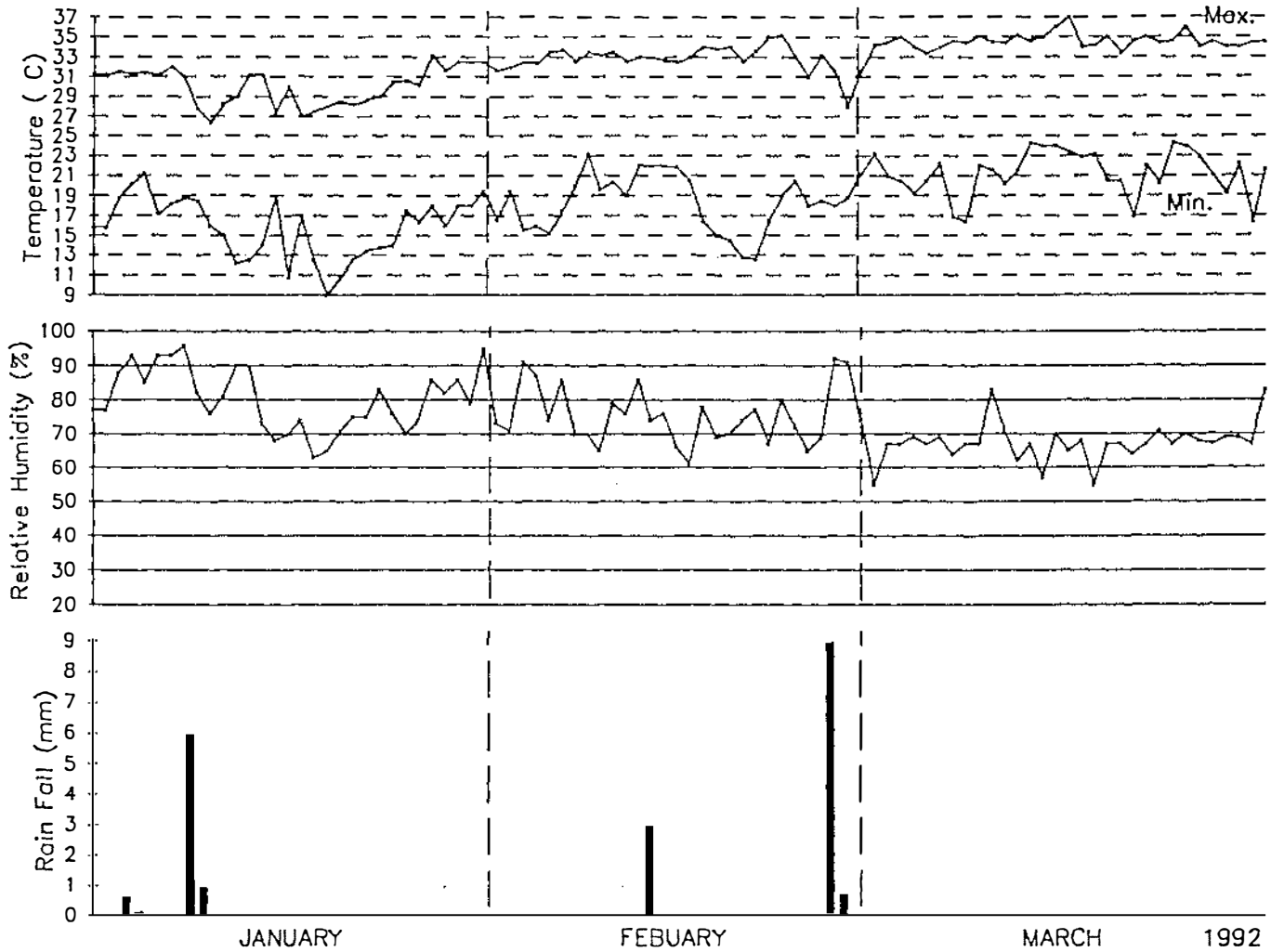

Figure A.2 Daily maximum and minimum temperature (°C), relative humidity (%) and rainfall (mm) in Thailand during January-March 1992 (Chapter 5).

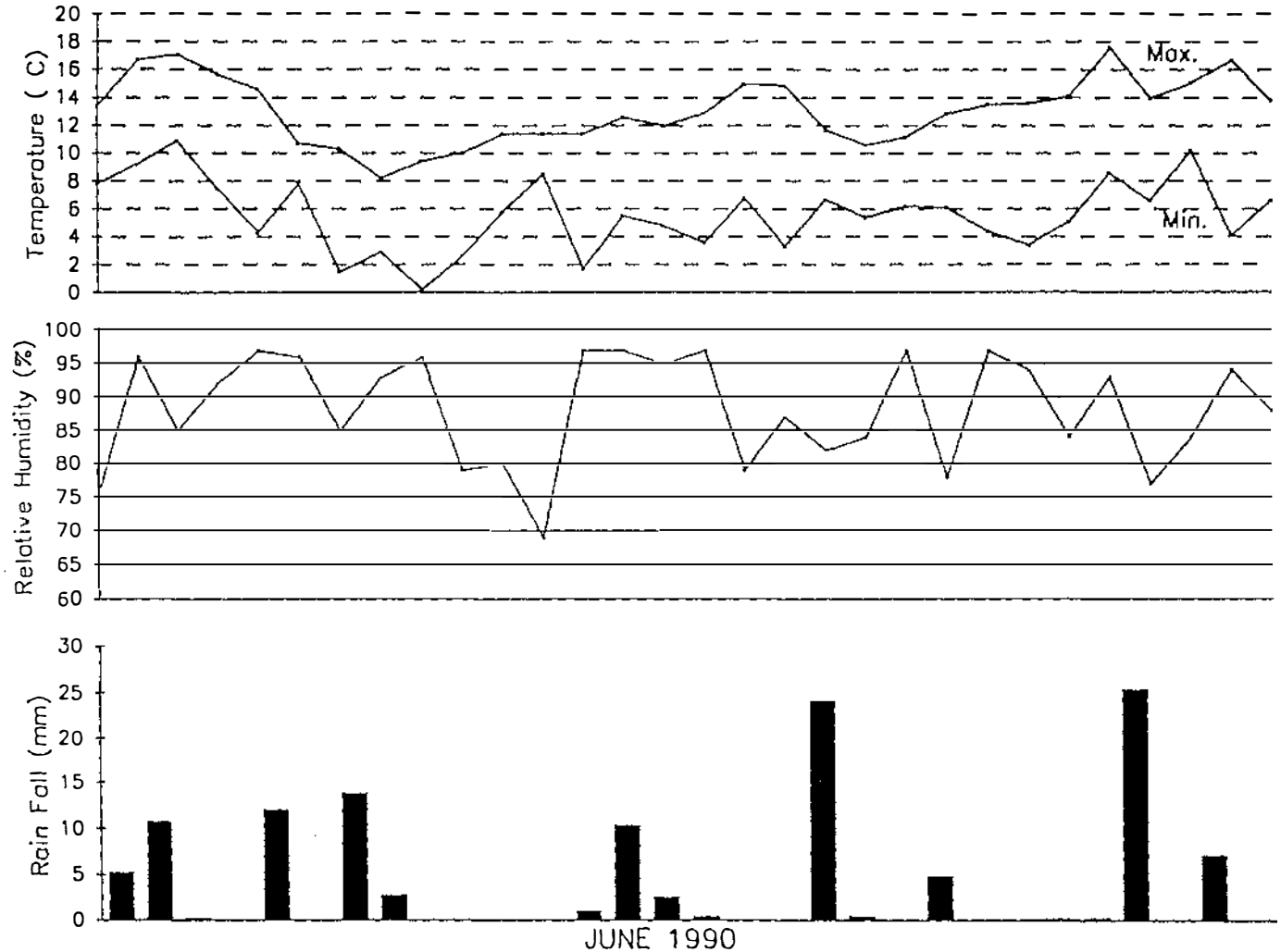

Figure A.3 Daily maximum and minimum temperature (°C), relative humidity (%) and rainfall (mm) in New Zealand during June 1990 (Chapter 8).

2 BACKGROUND OF EXPERIMENTAL SITES

2.1 THE DAIRY FARMING PROMOTION ORGANISATION OF THAILAND

The Dairy Farming Promotion Organisation of Thailand (DPO) was established by the government as a state enterprise in 1971. One of the DPO's first activities was to take over the Thai Danish Dairy Farm (TDDF), a training centre at Muaklek, Saraburi. The TDDF was a joint venture between the Thai and Danish Governments. The plans for the TDDF were initiated during His Majesty the King of Thailand's State Visit to Denmark in 1960. On 16th January 1962, the farm was inaugurated by Their Majesties the late King Federik IX of Denmark and King Bhumibol Adulyadej of Thailand.

At present, the DPO operates a full-scale industry, starting from inducing farmers to realise the importance of and the potential returns to be derived from dairy farming. It also provides training, knowledge and understanding of the various aspects of dairy farming to farmers. Counselling services on artificial insemination, preventive and curative treatment of animal diseases as well as basic amenities for dairy farming at low costs are also provided. DPO purchases raw milk and other products at guaranteed prices, then converts raw milk into various dairy products, and distributes the dairy products to the market at reasonable prices to enable the general public to buy highly nutritious food at low prices.

There are two stock farms. The original Thai Danish Farm in Muaklek occupied an area of 430 ha of which 320 ha is cultivated (including 140 ha of irrigated land). 90 ha is either mountain, river of stoney and the remainder consist of building, yards etc. Another farm is located at Chantuk, Nakorn-Rachasima, 40 km from Muaklek, occupying 1600 ha of which 1440 ha is cultivated. The cultivable land has been developed into permanent pastures using several grass species such as Guinea grass (*Panicum maximum*), Ruzi grass (*Brachiaria ruziziensis*), Buffel grass (*Cenchrus ciliaris*).

There is an increasing interest in pasture improvement through the introduction of forage legumes since a number of grass/legume combinations have been shown to be capable of high production. The present main perennial legumes mixed with pasture are Centro (*Centrosema pubescence*) and Verano stylo (*Stylosanthes hamata* cv. Verano).

Silage and hay is conserved from pasture and annual crops such as maize and sorghum in order to feed stock during the dry season. This enables the farms to supply sufficient roughage to the stock each year. In addition, the farms are also used as a pasture management study, research, grass stock and a demonstration for the farmers.

DPO has 4000 dairy cattle which about 230 cows are in milk and remainder are young stock and dry cows. They have resulted from the crossing of Native, Red Danish, Holstein Friesian and Sahiwal. The farm also acts as a rearing station for imports of purebred and crossbred dairy heifers.

2.2 MASSEY'S DAIRY CATTLE RESEARCH UNIT

The unit, run as a seasonal supply dairy operation, was established primarily for research purposes in 1959. The farm area is 45 ha, supporting an average of 120 milking cows and their replacements, as well as surplus heifer and bull calves for 3 months in spring.

The cows are Friesians of either high or low breeding index (having BIs of 128 and 100 respectively). 15-20 sets of identical twins of mixed breeds are also raised for research work.

The unit is situated on a wet clay soil - Tokomaru silt loam. The effective land area of the farm is divided into approximately 0.8 ha paddocks. Surplus spring pasture is stored as silage, with hay requirements being purchased locally. All pastures are fertilised with approximately 300 kg/ha of 30% potassic superphosphate annually, and approximately 200 kg/ha of urea annually.

2.3 MASSEY'S No.1 DAIRY FARM

The farm runs as a town supply dairy operation (Commercial Winter Milk Unit). The effective farm area is 108.6 ha, supporting an average 220 autumn calving milking cows and their replacements, as well as surplus heifer and bull calves.

3 MEASUREMENT TECHNIQUES

3.1 ANIMAL MEASUREMENTS

3.1.1 MILK YIELD AND COMPOSITION

Measurement periods of daily milk yield varied from experiment to experiment ranging from at least two consecutive days weekly to seven consecutive days weekly. Details of individual experiments have been given in the appropriate Chapters. Daily milk yield was taken as the sum of the individual evening milking and the following morning milk yield. Aliquot milk samples were taken for analysis of milk compositions.

Milk, milk fat, milk protein and milk lactose yields were calculated for individual cow and the figures averaged during the experimental period to give a mean value for daily yield per cow. These data were subject to analysis of covariance using average pre-experimental yield as covariates.

In Chapter 4, solids-not-fat percentage were obtained from the differences between %total solids and %fat. Total solids percentage were determined (AOAC, 1990) by weighing approximately 2.5-3 g milk sample into a weighed flat-bottom dish > 5 cm diameter. The samples were heated on steam bath for 10-15 minutes, then heated 3 h in hot air oven at 98-100°C. They were then cooled in desiccator, weighed quickly, and % residue calculated as total solids. Fat percentage was analysed using Milko Tester (Foss Electric Denmark).

In other experiments (Chapters 5 and 8), concentrations of milk compositions were analysed using Milko Scan (140A/B, Foss Electric Denmark).

3.1.2 LIVEWEIGHT AND CONDITION SCORE

Cows were weighed on two consecutive days immediately prior to the start of the experimental period. Subsequently, they were weighed weekly or fortnightly after the morning milking. The liveweight of each cow was then taken as the mean of the two consecutive weights.

The liveweight change was defined as the difference in liveweight between the start and the end of the experimental period and divided by the number of days of the experimental period.

In Chapter 8, body condition score for each cow was assessed at the same time as the live weight. The score system used was that reported by Scott *et al.* (1980), with a range of 1-10. The score of the two consecutive days were averaged at the start of the experimental period.

Body condition score change was calculated in the same way as for the liveweight change stated above.

Both liveweight and condition score data were subject to analysis of covariance to test for treatment effects at the end of the experimental period. Changes in liveweight and condition score over the experimental period were subject to analysis of variance to test the difference due to treatments.

3.1.3 DRY MATTER INTAKE (DMI)

3.1.3.1 Difference Method

In the indoor experiments (Chapters 4 and 7), the amount of roughage consumed daily by each cow was measured by the difference method i.e. roughage intake was the difference between roughage offered and roughage refused.

In grazing experiments (Chapters 4 and 8), the average amount of pasture consumed by each cow of each group was estimated as the difference between the pre-grazing herbage mass and the residual herbage mass, multiplied by the area allocated daily and divided by the number of cows grazing during that time.

3.1.3.2 Chromium Dilution Method

In Chapter 8, individual cow DM intakes were estimated using chromium sesquioxide (Cr_2O_3) as an indigestible marker (Le Du and Penning, 1982). Dry matter intakes were estimated using estimates of faecal output and *in vitro* DMD according to the following equation:

$$\text{DMI (kgDM/day)} = \frac{\text{Faecal Output (kgDM/day)}}{1 - \text{DMD}}$$

Measurement of Faecal Output

Individual cows were dosed with a controlled-release Cr_2O_3 capsules (CRC, Captec NZ Ltd., Auckland) at the start of the experiment. The first 6 days after dosing were used to allow the concentration of Cr_2O_3 to stabilise throughout the digestive system. From days 7 to 14 samples of faeces were collected once daily (between 10.00am and 14.00pm) from each cow as it defecated in the paddock. Faecal samples for each cow were bulked for two 4 day-periods and stored at -4°C.

Faecal samples were thawed, thoroughly mixed, subsampled, and oven dried at 80°C for 7 days. Dried samples were ground to pass a 2 mm sieve and analysed for chromium by spectrophotometer according to method A of Fenton and Fenton (1979). Faecal output was calculated as follow:

$$\text{Faecal output (kgDM/day)} = \frac{\text{average release of } Cr_2O_3 \text{ (gm/day) x 0.001}}{Cr_2O_3 \text{ in faeces (gm/gm DM faeces)}}$$

3.2 SWARD MEASUREMENTS

3.2.1 HERBAGE MASS PRE- AND POST-GRAZING

In Chapter 4, herbage enclosed within three 1 m^2 (50 x 200 cm) quadrats were cut with a hand sickle at 15 cm above ground level for each treatment. After cutting, the three herbage cuts were bulked and fresh weight were recorded. Subsamples were taken for DM determination.

In Chapter 8, herbage enclosed within ten 0.1875 m^2 quadrats, to provided a stratified random sampling within each days area within each paddock, were cut to ground level. A sheep shearing hand piece powered by a mobile petrol motor was used to cut the herbage samples. This operation was always carried out by the same operator, to minimise the variability associated with the technique (Thomson,1986).

After cutting, the ten herbage cuts were bulked and washed to remove soil contamination and dried at 70-80°C for 36 hours for dry matter determination. A subsample bulked from each pre-grazing cutting, from each treatment and from each paddock was collected for chemical analysis. The dry weight of total herbage cut was used to estimate pre- and post-grazing herbage mass (kgDM/ha).

3.2.2 HERBAGE ALLOWANCE

Herbage allowance (kgDM/cow/day) from each break was calculated by multiplying herbage mass (kgDM/ha) by the area grazed (m^2) each day and divided by the number of cow grazed.

3.2.3 HERBAGE COMPOSITION

3.2.3.1 Chemical Analysis

Dried samples of total herbage in the sward were bulked per paddock to facilitate herbage composition measurements. They were then ground through 1 mm screen and were subject to analyses for:

a) Total nitrogen concentration - g/kg - (Kjeldahl),
b) Ash concentration - g/kg - (500°C/24 hrs),
c) *In vitro* digestibility (Roughan and Holland,1977).

Calculation of crude protein was made by using the commonly-accepted equation that:

$$CP = 6.25N$$

where CP = Crude protein (%)
N = N concentration in the dry matter (%)

Calculation of metabolisable energy was made using the assumption of that:

$$M/D = 0.16DOMD \text{ (MAFF, 1975)}$$

where M/D = ME concentration in the dry matter
DOMD = Digestible organic matter in the dry matter from *in vitro* analyses.

3.2.3.2 Digestibility, Measured *In Vivo*, for Pasture Cut in Two Strata

At the same time as the experiment described in Chapter 8 was in progress, 8 sheep were used to measure the *in vivo* digestibility of herbage cut from two strata in a pasture similar to that grazed by the cows.

Eight female sheep were randomly assigned into two treatment groups (four sheep per group). One group was fed on herbage from the upper strata (15-20 cm cutting height). The other group was fed on herbage from the bottom strata (6-8 cm cutting height). Sheep were allowed to become accustomed to their diets for 5 days before faecal collection started. Cut herbage was offered to the sheep *ad libitum* into two allotments per day. Herbage refusals were removed, individually weighed and subsampled for DM determination daily. The total collection period was divided into two consecutive 5 day collection periods. Herbage to be fed to the sheep was cut each morning by Sickle Bar Mower.

The cut herbage was thoroughly mixed and subsampled for DM determination. A separate subsample was frozen and bulked over a 5 day collection period and subsequently freeze dried and ground to pass 1-mm screen for *in vitro* digestibility determination.

Faeces voided by each sheep were collected daily, stored in the freezer and bulked over a 5 day collection period. At the end of each 5 day collection period, faeces were weighed individually for each sheep, thoroughly mixed and subsampled in triplicate for DM determination. The DMD of the herbage was calculated as:

$$DMD = \frac{DMI - FDM}{DMI} * 100$$

where DMD = Dry matter digestibility
DMI = Dry matter intake
FDM = Faeces dry matter

For the calculation of OMD, the samples of herbage and faeces were subject to ashing (500°C for 12 hours) and the OM in each determine. OM values were then substituted for DM in the above equation.

4 STATISTICAL ANALYSIS MODELS

4.1 ANALYSIS OF VARIANCE

Sward (HM, RHM, HA), intake (DMI and MEI) and live weight change data were analysed using analysis of variance (Steel and Torrie,1986) as the following model.

$$y_{ij} = \mu + \alpha_i + e_{ij}$$

where:

y_{ij} = the observation on the j^{th} individual exposed to the i^{th} treatment.

μ = the unknown population mean.

α_i = the effect of the i^{th} treatment.

e_{ij} = the random error associated with the j^{th} individual exposed to the i^{th} treatment. It is assumed that e_{ij} is normally distributed with mean 0 and variance σ^2.

4.2 ANALYSIS OF COVARIANCE

Final liveweight and condition score were analysed using the analysis of covariance (Steel and Torrie, 1986) as the following model:

$$y_{ij} = \mu + \alpha_i + \beta x_{ij} + e_{ij}$$

where:

y_{ij} = the observation on the j^{th} individual exposed to the i^{th} treatment.

μ = the unknown population mean.

α_i = the effect of the i^{th} treatment.

βx_{ij} = the regression coefficient of y_{ij} on x_{ij}

e_{ij} = the random error associated with the j^{th} individual exposed to the i^{th} treatment. It is assumed that e_{ij} is normally distributed with mean 0 and variance σ^2.

4.3 ANALYSIS OF COVARIANCE (REPEATED MEASUREMENT)

Yields of milk, milk fat, milk protein and milk lactose, milk compositions, and live weight and condition score were analysed using the repeated measurement analysis of covariance (Gill and Hafs, 1971; Morrison, 1976; Bryant and Gillings, 1985) as the following model.

$$y_{pij} = \mu_p + \alpha_{ip} + \beta_p x_{ij} + e_{pij}$$

where:

y_{pij} = the observation on the j^{th} individual measured in the p^{th} week and belonging to the i^{th} treatment.

μ_p = the overall mean together with the effect of the p^{th} week.

α_{ip} = the effect of the i^{th} treatment in the p^{th} week.

β_p = the regression coefficient of y_{ij} on x_{ij} in the p^{th} week.

x_{ij} = the initial observation on the j^{th} individual in the i^{th} treatment.

e_{pij} = random residual effects, which are assumed to be identically and independently distributed within the p^{th} week, but there being covariance across weeks.

4.4 ANALYSIS OF VARIANCE (LATIN SQUARE DESIGN)

In Chapter 6, intakes of hay DM, concentrate DM and water were analysed using analysis of variance in the Latin Square (Steel and Torrie, 1986). Digestibilities of DM and protein, degradation of DM and protein in hay and concentrate were also analysed using the following model:

$$y_{ijk(t)} = \mu + t_i + p_{ij} + s_{ik} + u_{(t)} + t_i{}^*u_{(t)} + e_{ijk(t)}$$

where:

$y_{ijk(t)}$ = the observation on the t^{th} treatment in the j^{th} row (period) and k^{th} column (sheep) within the i^{th} temperature.

μ = the population mean.

t_i = the fixed effect of the i^{th} temperature condition.

p_{ij} = the random effect of the j^{th} period within the i^{th} temperature condition assumed to be normally and independently distributed with mean 0 and variance $\sigma_p{}^2$.

s_{ik} = the random effect of the k^{th} sheep within the i^{th} temperature condition assumed to be normally and independently distributed with mean 0 and variance $\sigma_s{}^2$.

$u_{(t)}$ = the fixed effect of the t^{th} treatment.

$e_{ijk(t)}$ = the random residual effect unique to $y_{ijk(t)}$ which is assumed to be normally and independently distributed with mean 0 and variance $\sigma_e{}^2$.

4.5 ANALYSIS OF VARIANCE (LATIN SQUARE DESIGN REPEATED MEASUREMENT)

In Chapter 6, rumen ammonia concentration, rumen pH and rumen VFA were analysed using the following model:

$$y_{hijk(t)} = \mu_h + t_{ih} + p_{ijh} + s_{ikh} + u_{h(t)} + t_{ih}{}^{*}u_{h(t)} + e_{hijk(t)}$$

where:

$y_{hijk(t)}$ = the observation on the t^{th} treatment in the j^{th} row (period) and k^{th} column (sheep) within the i^{th} temperature measured at h^{th} hour.

μ_h = the population mean together with the effect of the h^{th} hour.

t_{ih} = the fixed effect of the i^{th} temperature condition in the h^{th} hour.

p_{ijh} = the random effect of the j^{th} period within the i^{th} temperature condition at h^{th} hour, and assumed to be normally and independently distributed with mean 0 and variance $\sigma_p{}^2$.

s_{ikh} = the random effect of the k^{th} sheep within the i^{th} temperature condition at h^{th} hour, and assumed to be normally and independently distributed with mean 0 and variance $\sigma_s{}^2$.

$u_{h(t)}$ = the fixed effect of the t^{th} treatment measured at h^{th} hour.

$e_{hijk(t)}$ = the random residual effect unique to $y_{hijk(t)}$ which is assumed to be normally and independently distributed within the h^{th} hour with mean 0 and variance $\sigma_e{}^2$.

The following symbols will be used throughout this thesis to determine the level of significance of differences between means.

***	Significant difference at the probability < 0.001
**	Significant difference at the probability < 0.01
*	Significant difference at the probability < 0.05
NS	Not significant difference.