EFFECT OF SUPPLEMENTARY HAY FED TO NON-LACTATING COWS OFFERED TWO ALLOWANCES OF PASTURE

A thesis presented in partial fulfilment
of the requirements for the degree of
Master of Agricultural Science in
Animal Science at Massey University
Palmerston North, New Zealand.

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1988

ABSTRACT

In New Zealand, the system of production of the seasonal supply farms is based on grazed pasture and small quantities of conserved herbage throughout the year. The efficiency with which that conserved pasture is utilized by the animal and its effect on the sward will affect the profitability of the system. The objective of the present study was to assess the effect of hay supplementation at two different herbage allowances during the winter. Pregnant, non-lactating Friesian cows were randomly allocated to four treatments in a 2x2 factorial design. The four treatments were: Low herbage allowance with hay (LA+) or without hay (LA), and high herbage allowance with hay (HA+) or without hay (HA). Hay was fed at 5 kgDM/cow/daily, and the two pasture herbage allowances were 9.1 and 13.4 kgDM/cow/daily.

Higher herbage allowance increased the herbage dry matter (DM) intake, total DM intake, total metabolizable energy (ME) intake and residual herbage mass.

Supplementing with hay resulted in increases in total DM intake and ME intake, despite the low concentration of the hay compared with the herbage, and decreases in herbage DM intake at both herbage allowances. The decreases in herbage intake were 0.28 and 0.40 kg herbage DM eaten per kg hay DM eaten, at the lower and higher herbage allowances respectively. The corresponding values, expressed as MJME, were decreases of 0.44 and 0.65 MJME from herbage per MJME eaten as hay. The decreases in herbage intake resulted in increases in residual herbage mass at both allowances.

The final liveweight and body condition were increased by the higher herbage allowance and by Hay supplementation. However, maternal liveweight gain was higher for HA than for HA+ cows.

There were large increases in water drunk (by 2.1 and 1.5 fold) by the supplemented cows. However, supplementation did not increase the total water consumed. The 'extra' water drunk per kg hay DM eaten was higher at the low than at the high allowance.

Hay supplementation reduced the time the cows spent grazing and increased the ruminating time during the daytime.

The results of the present study emphasize the importance of hay as a supplement during the winter. It is important to consider the reported effects when planning the use of hay as a supplement for non-lactating cows.

ACKNOWLEDGEMENTS

The author wishes to thank the following people:

To my supervisor: Dr. C.W. Holmes for invaluable guidance, assistance, advice and encouragement throughout his studies.

Many post-graduate students and staff members of the Animal Science Department, for their personal and professional interest in this study.

Prof. J. Hodgson, Dr. A.C.P. Chu, Dr. C. Hoogendoorn for helpful discussion with various aspects of the study.

R.A. McClenaghan and A. Ortega for their technical assistance while carrying out the experiment.

J.M. Rendel for helpful suggestions and guidance with statistical procedures.

C.A. Butts and R.A. Watson for their help with chemical analyses.

The personnel of the Dairy Research Unit and the Animal Physiology Unit for their asssistance during the experiment.

Mr. R. Rangel and Mrs. D. Beatson for their suggestions and reading of the manuscript.

The New Zealand Government for the scholarship that allowed the author to carry out his studies and The Universidad Nacional de Colombia for allowing him to study in New Zealand.

Lastly, but the most important to Maria Jose, for her patience, comprehension, support and encouragement throughout all the time of his post-graduate studies.

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INTRODUCTION

The knowledge of the inter-relationships between plants and animals is fundamental to progress in the control and manipulation of grazing systems (Hodgson,1985b). The overall efficiency of a grazing system must imply the soil-plant-animal-environment complex, considering not only the biological benefit, but also the economical one.

The efficiency of utilization of grassland in New Zealand is well recognized (Scott,1982; Peel,1986). The strength of New Zealand's agriculture is largely dependent on the efficient use of pastoral grazing lands and a minimum use of capital intensive farm management systems. Its success is based on the integration of physical, animal, environmental, socio-economical and human factors. In this system, the cattle are fed on grazed pasture and small quantities of conserved herbage throughout the year.

An important aim of farmers is to maximize income or profits from given resources. This requires a system which balances per head and per hectare production in such a way to maximize profit. A high profitability is jeopardized by the seasonal fluctuations in pasture growth, that generate deficits during the winter and summer.

Pasture conservation has been used as an aid to grazing management during the spring and as a means of converting surplus of green material into well preserved products, to fill the deficits between pasture growth and animal requirements (Holmes and Wilson,1984). This should be done with minimal losses in quality and quantity at reasonable cost.

In seasonal supply farms in New Zealand, surplus pasture is conserved as hay or silage in spring, and fed back to stock as part of a maintenance or supplementary ration during the winter. Hay has been used as an important feed supply for feed budget (Ridler and Holmes,1986)

Pasture hay and silage occupied an area of approximately 436,310 ha, where 73% was conserved as hay and the remaining as silage. For dairy cattle farming,during 1985 the estimated quantities of grass and clover hay and silage produced were about 7200,000 and 1'063,000 tons of fresh matter respectively (D.S.N.Z.,1985).

The present study reported the effects of hay supplementation during the winter in grazing, non-lactating, pregnant cows allocated to two herbage allowances.

CHAPTER 2

2 REVIEW OF LITERATURE

2.1 MANAGEMENT OF FEEDS AND FEEDING DURING THE WINTER.

The winter management for dairy farms with spring calving herds has several aims that will affect the productivity of the whole farm during the year. The priorities of autumn-winter management are to ensure:

- The accumulation of sufficient high quality pasture to ensure high levels of feeding in early lactation.
- That the cows are in adequate body condition when they calve at the end of winter.
- Achieving conditions to enhance the cool season growth of pasture, prevent the accumulation of dead material and wastage of pasture and avoid the damage of pasture by pugging.

In many cases these aims cannot be fulfilled simultaneously. The pasture cover in spring on a particular situation depends on factors such as winter pasture growth rate, time of calving and pattern, expected level of production and stocking rate (Milligan et al,1987). In general, the quantity recommended as cover present during early lactation is between 1400-1800 kgDM/ha (Milligan et al,1987), However, Bryant (1984) and Holmes and Wilson (1984) suggested around 2000 kgDM/ha pasture cover for early spring.

Hay, fed during the winter as a supplement with restricted quantities of pasture to non-lactating cows, can affect all of these aims, but in particular the first and second.

The effects of hay are due to:

- A pasture-sparing effect,because hay included in the diet, allows some pasture to be removed from the diet. This is likely to have a direct effect on the quantity of pasture present on the farm at the end of winter.

- A dietary-energy boosting effect, because the feeding of hay, may allow the cows to be given a higher feed intake than if they had been forced to rely solely on grazed pasture. This will obviously have a direct effect on the cow's condition at the end of winter.
- Finally, the pasture-sparing effect may cause an increased rate of pasture regrowth during winter, due to a reduction in the intensity of grazing and the consequent increase in leaf area remaining after grazing. This effect, if present, will influence the quantity of pasture present on the farm at the end of winter.

This review of literature will discuss:

- The management of feeding during the winter on the seasonal supply dairy farm, and the role of supplementary feeding.
- The many factors affecting the use of supplementary feeding.
- The factors which control the food intake of cattle in general, and grazing cattle in particular.

2.1.1 Level of Feeding in Early Lactation.

Underfeeding during early lactation resulted in a reduction in production, not only in milk yield but also in liveweight and condition score (Broster,1971,1972; Grainger et al,1982; Broster and Broster,1984; Broster et al,1984, Stockdale et al,1987). Bryant and Trigg (1982) summarized several experiments from Australia and New Zealand and concluded that on average a 38% restriction in DM intake resulted in a reduction of 24% in milkfat yield, generally reduced protein and SNF content of milk.

The time (Grainger and Wilhelm,1979) and the duration of the underfeeding (Broster and Broster,1984) affected the animal performance. Bryant (1980) and Treacher et al(1986) concluded that good feeding after calving will not entirely compensate for poor feeding before calving, if the cows calve in low body condition score (Grainger et al,1982). Although a positive interaction between body condition at calving and feeding level in weeks 1-5 for milk and milkfat yield (20 weeks) was found by Grainger et al (1982).

Residual Effects The consequences of underfeeding postcalving are not only related to the period of underfeeding but also to the period immediately after it. Underfeeding during early lactation has shown a residual effect after the period of underfeeding. Bryant and Trigg (1982) reported an average residual effect which was 0.5 times the immediate effect of underfeeding. This contrasted with the early information of a residual effect of three or more times the immediate effect (Wallace,1958; Broster,1972).

Broster and Thomas (1981) suggested that the residual effects are affected by the level of feeding after the underfeeding. Milk production is affected by the quantity of feed on offer and the body reserves mobilized (Broster and Broster,1984).

2.1.2 Liveweight, Body Condition at Calving and its Effect on Milk Production.

Body condition score is related to the fat content of the animal's body (Gray et al,1981) and may provide a better estimate of the body energy reserves than would be provided by measurement of the liveweight (Holmes et al,1981). Body condition is a reliable guideline to determine the energy feeding level during the dry period (Wiktorsson,1979).

The absolute liveweight or body condition at calving, and not the rate of change of liveweight or body condition, is the important factor affecting future milk yield (Rogers et al,1979; Grainger et al,1982; King et al,1985). Neither the type of diet or the pattern of feeding before calving had a measurable influence on subsequent liveweight, milk yield or composition if the cows calve at similar weight (Hutton,1972; Rogers et al,1981).

The body reserves achieved before calving become available for milk production in early lactation. Hutton (1972) and Hutton and Parker (1973) reported that the cows calving in better condition produced more milkfat. Rogers et al (1979) concluded from a series of experiments that body condition or liveweight of the cows at calving is the important factor affecting subsequent milk production rather than the rate of change. Grainger et al (1982) found a positive linear correlation between condition score at calving and milk yield for the range of 3-6 body condition score(scale 1-8). Similar response was reported by Holmes et al (1985) for high and low breeding index cows.

Bryant (1985) recommended that condition score at calving should be about 5 (scale 1-10). An extra 10 kg of liveweight at calving increased milkfat yield in 2.9 kg (Bryant,1982). The possible reason of the lower yield of the cows in poor condition at calving was that they partitioned a higher proportion of feed energy to recover liveweight at the expense of milk production than did cows in better condition.

Fat cows at calving ate less than thin cows (Bines,1976; Forbes,1980; Broster and Thomas,1981; Holmes et al,1981; Grainger and McGowan,1982; Bines and Morant,1983). Grainger et al (1982) reported that the effect disappeared by the 8 week of lactation. Meanwhile Kroll et al (1986) found that cows of lower condition score at calving achieved maximum DM intake earlier than those of higher score.

Cows calving in thinner body condition ate more pasture initially than the fatter cows within a limit. Very thin cows at calving do not express their maximum theoretical intake, possibly due to depletion of body protein levels (Bines,1979). However, cows on extremely fat body condition 4.0 (scale 1-5) produced less milk per lactation, and lost more liveweight after calving (Reid et al,1986).

Milk fat content of the cows of higher body condition was higher compared with cows with lower condition score (Grainger et al,1982).

Gray and Matthews (1982) have shown that the condition score was useful as a guide to feeding management during the winter.

Body condition at calving had a positive effect on reducing the anoestrus interval (5.7 days/B.C.).(Grainger et al,1982). However, Treacher et al (1986) did not find a significant difference in reproductive performance between thin and fat cows, although the thinner cows tended to perform better.

To achieve a winter feed plan it is necessary to integrate factors like: drying off date, condition score, breed, calving date and pattern,previous summer and autumn grazing management, level of feeding after calving, supplements, pasture restriction and rotation length during the winter.

2.1.3 Winter Management.

2.1.3.1 Winter rotation.

The influence of winter rotation on pasture and animal performance has been studied extensively during recent years in Australia and New Zealand. Slow rotations (80-120 days) during the winter, resulted in large differences in the amount of pasture present in early lactation compared with fast rotations (Brougham,1970; Bryant and Cook,1980; Santamaria et al,1980;

Holmes and Hoogendoorn,1985; Bryant and L'Huiller,1986). The influence of the amount of pasture present at calving and its consequences is discussed briefly.

Pasture Growth during the Winter The influence of winter rotation on winter pasture growth is contradictory. Santamaria and McGowan (1982); Ryan (1986) and Hoogendoorn (1987) observed that the slow winter rotation increased the growth rate during the winter. This effect was probably related to the higher LAI and minimal losses through decay and death, but Bryant and Cook (1980) and Maguire et al (1984) found no significant differences in pasture growth during the winter between the large and slow winter rotation. Similar results were reported by Parmenter and Boswell (1983) working with sheep.

However, Brougham (1970) reported a higher winter growth for the frequent (42 days) rotation compared with the infrequent (128 days) one. The differences reported for winter growth can be related to environmental conditions (Bryant,1984), or to the fact that the effect of rotation length is confounded with the effect of severity of grazing. Around 2200 kgDM/ha was considered the critical RHM to achieve the maximum growth rate of the pasture during the winter (Gray and Matthews,1982); the botanical composition and structure of a sward can be manipulated by the grazing management (Hoogendoorn,1987; Bryant and Sheath,1987). The winter rotation changed the distribution of pasture present in the farm (Bryant and Cook,1980; Maguire et al,1984).

Pasture Quality The quality of pasture on the slow rotation during the winter was lower than the quality of the fast rotation pasture (Santamaria and McGowan,1982; Ryan,1986; Hoogendoorn,1987). This effect was reflected in lower contents of grass leaf, clover content and digestibility, and higher contents of grass stem and dead material (Brougham,1970; Holmes and Hoogendoorn,1985; Ryan,1986; Hoogendoorn,1987).

Pasture Growth during the Spring The winter management can have major effects on subsequent growth during the spring (Lancashire,1982; Ryan,1986; Hoogendoorn,1987), although this effect was not observed by Bryant and Cook (1980) and Santamaria and McGowan (1982). Autumn and winter were important for replenishment of tiller density; extremes of winter management or stocking rate had no effect on the proportion of tillers or the tiller density (L'Huiller,1987).

Rate of Growth during the Winter and Pugging The rate of growth during the winter has been shown to be affected by factors like: minimum temperature, hours of light, leaf area index, resistance to treading damage and carbohydrates reserves (Smeatham,1984).

The extent of the damage caused by treading depends on stocking density, soil type, rainfall and plant resistance. Grazing cattle may affect herbage production by treading, either indirectly through effects on the soil or directly through effects on the herbage destroying growing points, leaves, stems or roots (Frame,1976; Bowler,1980; Charles,1980), affecting plant growth and persistency (Coleman,1983) and eventually botanical changes. Wet winters and naturally poorly drained soils have limited herbage utilization under long rotation with high animal densities with cattle (Brougham and Cosgrove,1985).

Effect on Animal Performance The effects of winter rotation on subsequent animal performance are also contradictory. Bryant and Cook (1980) reported a higher milkfat production (10 -15%) for the slow winter rotation compared with the fast rotation not only during early lactation but also during the whole lactation. On the other hand, Bryant and Holmes (1985) and Bryant and L'Huiller (1986) found little effect on total milkfat yield, liveweight or body condition, probably because the cow performance decreased in late lactation for the slow

compared with the fast rotation. Nevertheless Ryan (1986) and Hoogendoorn (1987) found, in short term studies, that cows grazed on short rotation pasture produced more milkfat during the spring compared with those grazed on long rotation pasture, probably due to the higher quality of the herbage.

2.1.3.2 Herbage allowance

Herbage allowance has been recognized as a very useful management procedure for regulation of herbage intake for short grazing periods (Bryant,1980; Hodgson,1976,1984). It will determine the rate at which animals graze down into limiting horizons within the sward (Hodgson,1979b). The amount of herbage consumed during the dry period has been generally related to the quantity of the pasture offered (Nottingham,1978; Holmes and McClenaghan,1980; Ngarmsak,1982) (Figure Nº 5.2.2).

2.1.3.3 Drying off date.

Drying off date is important at high stocking rates (Campbell and Bryant,1978; Bryant,1982). It determines the extent of change in body condition in late lactation and the quantity of feed required to replace that condition, and may alter the amount of feed consumed during the lactation and as a consequence the quantity of pasture reserves present at the end of lactation. The factors affecting the drying off date and its influence on feed management and productivity have been discussed in detail by Campbell and Bryant (1978); Bryant (1980;1982;1984) and Wilson and Davey (1982).

2.1.3.4 Calving date and pattern.

It is recognized that if cows are going to rely on grazed pasture, then lactation must be made to coincide as closely as possible with the period of rapid pasture growth (Simmonds,1985).The calving date and its pattern influences the herd's feeding requirements and level of feeding (Monteath,1973; Bryant,1982). The influence of calving date and its pattern on the animal performance, winter management, pasture production and conservation requirements have been discussed by Hutton (1974); Bryant (1982; 1985); McMillan et al (1984; 1985); Bryant and Holmes (1985) and Coats (1985).

2.1.3.5 Supplementary feeding during the winter.

In New Zealand, supplements are used mainly during the winter and during the summer, when the quantity of pasture growing is less than the quantity of pasture required by the animals. Although they provide less than 10% of annual feed requirements (Bryant,1983), they commonly provided from 20-80 % of the feed intake during summer or winter (Wright et al,1980). In very wet conditions hay and silage may be the sole source of feed for considerable periods. The type of supplements utilized are mainly conserved pasture as hay or silage conserved during the spring.

The main role of conservation in New Zealand is as an aid to pasture management and not that of transferring feed from times of surplus to times of shortages (Bryant,1982,1984; Thomson et al,1984). Although the extra costs incurred by shifting feed from times of surplus to times of deficit must be covered at least in the long term (Marsh,1978). The subsequent refeeding of the conserved grass has the potential of increasing efficiency of grazing (Bryant and Holmes,1985). The

use of supplements during the winter has been a common practice designed to help reach those aims of the winter grazing management.

Effect on Saving Pasture The use of supplements during the winter is recommended for saving pasture in order to ensure high levels of feeding in early lactation during the design of feed planning (Frengley,1973; Monteath,1973; Riddler and Holmes,1986; Milligan et al,1987). This is achieved by reducing the amount of pasture eaten or as suggested by Rogers (1985) that there is pasture spared during supplementation and might be carried forward providing additional feed.

If there is substitution of the pasture by offering supplement, it reduces the severity of defoliation increasing the residual herbage mass. This effect may increase the winter growth and consequently, cause an additional increase in the quantity of pasture present in early lactation (Hoogendoorn,1987).

Effect on Animal Performance In general, the quantity of pasture grown during the winter is less than the quantity required for maintenance of the non-lactating, pregnant cow at high stocking rates. Therefore, supplements have been utilized to maintain the liveweight of the cows at low levels of pasture intake. Furthermore, they have been used to recover the liveweight or condition lost during the late lactation. This last characteristic depends on the quality and quantity of the supplement offered. Dry cows fed just on hay (DMD 52%) only maintained the body condition (Rogers,1985).

The effect of supplementation on treading is controversial. Generally deleterious effects of treading can be seen around water or feeding trough areas where the sward can completely be destroyed and the soil severely damaged (Charles,1980). However, supplementation can decrease the time the cows spent grazing decreasing the posibilities of damage by

treading, if the cows reduce the time spent walking.

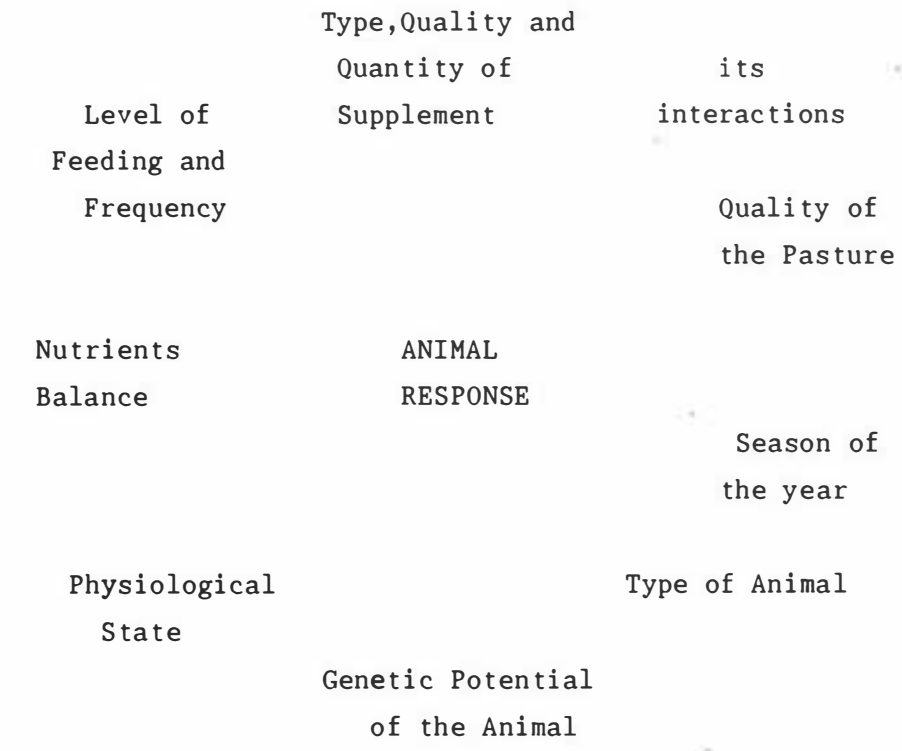
2.2 SUPPLEMENTATION.

In general, the use of supplements for grazing animals have been proposed as an aid to:

- avoid underfeeding (during shortages of pasture),
- overcome deficits of feed during certain times of the year,
- to increase animal performance (balance diet),
- transfer feed to reduce the gap between pasture production and animal requirements,
- as a buffer to maintain stocking rate (despite the losses during the conservation) or to increase stocking rate when the supplement is purchased.

Several factors influence the response of the animal to the supplementation as is shown in Figure Nº 2.2.1.

Figure Nº 2.2.1. Factors affecting the Animal Response to Supplementation.



Usually the response to supplementation is measured immediately. However, the residual effects associated with supplementation can be important (Wallace,1957; Broster,1971;1972; Bryant and Trigg,1982; Kempton,1983; Broster and Broster,1984).

The majority of the information available is for lactating cows fed with concentrates.

2.2.1 Level of Feeding.

It is generally accepted that when pasture of good quality is not restricted, the animal response to supplements is reduced and the substitution rate of pasture by the supplement is high (Leaver *et al*,1968; Journet and Demarquilly,1979; Meijs,1981; Bryant and Trigg,1982; Kempton,1983; Leaver,1985).

Substitution Rate In general, supplementation causes a decrease in herbage intake, but an increase in total DM intake, due to partial substitution of grazed herbage by the supplement (Hutton and Parker,1966; Stockdale *et al*,1981; King and Stockdale,1981; Holmes and Curran,1967; Meijs and Hoekstra,1984; Stockdale and Trigg,1985; Stakelum,1986; Grainger,1987; Bryant,1978; Bryant and Trigg,1982 and Jennings and Holmes,1985).

Animal Performance The effect on animal performance (kg FCM/kg DM supplement) decreased as the overall level of feeding increased (Leaver *et al*,1968; Dulphy and Demarquilly,1983; Grainger,unpublished; Stockdale and Trigg,1985; Leaver,1986). The effect of supplementation on liveweight changes is not

always reported. However, Hutton and Parker (1966); Stockdale et al (1981); King and Stockdale (1981) and Bryant and Trigg (1982) have observed a tendency for greater increases in liveweight gains due to supplements, when the overall level of feeding is increased. Marginal response (kg FCM/kg DM supplement) can be increased by the milk potential of the cows. Coulon et al (1987) reported a marginal response of 0.6, 1.2 and 1.6 respectively for cows of a potential of milk yield of 26 kg, 26-29 kg and > 29 kg. The latter authors suggested that this last effect can be confounded in some of the experiments.

There is limited information about the use of hay supplementation for grazing cows with different levels of feeding.

2.2.2 Type of Supplement.

Several types of supplements have been used in New Zealand for grazing cows. They can be divided in: Supplements associated with a pasture conservation methods (silage,hay), concentrates, crops (lucerne, maize, millet, sorghum, rapeseed, chamboellier,etc.) and crop by-products (potatoes, kiwifruit, different fruits, other tubers, peas, etc.). The utilization of those supplements depends on availability, price, animal requirements and/or animal response.

Substitution Rate The effect of type of supplement on DM substitution rate is contradictory (Umoh and Holmes,1974; Vadiveloo and Holmes,1979; Bryant and Trigg,1982; Aston et al,1986). Probably due to the confounding effects of level of feeding, relationship with pasture quality or balance of the whole diet. However, if the diet is deficient in one nutrient, supplementation with that nutrient can increase the intake of pasture. For example protein supplementation can increase pasture intake when the diet is deficient in protein

(Kempton,1983; Aston et al,1986; Moran et al,1986).

Hay Supplementation The information available comparing hay as a supplement with other supplements is scarce. The DM substitution rate reported by Eldridge and Kat (1980) and Stockdale et al (1981) and Phillips and Leaver (1985a) for hay supplementation for non-lactating and lactating cows during the whole lactation was within the range described for DM substitution rate for other feeds (Leaver et al,1968; Journet and Demarquilly,1979; Bines,1979; Meijs,1981; Leaver,1986).

In New Zealand, Hutton and Parker (1966) fed restricted grazing cows during early lactation with hay and showed that hay supplementation increased milk yield and liveweight gains, however, the difference in liveweight could be associated with higher gut-fill. In Ireland, Walsh (1969) fed grazing dairy cows with or without concentrate and hay ad libitum and observed different response to both supplements, concluding that the digestibility of the supplements affected the animal response per kgDM supplement. In Australia, Stockdale et al (1981) and King and Stockdale (1981) fed hay of high digestibility and reported that when the quality of the supplement was similar to the pasture, the nutritive value of the whole diet was not affected by associative effects.

Animal performance The evidence about the effects of type of supplement on animal performance is conflicting, depending not only on its quality, quantity, frequency of feeding,form and palability, but also the interactions with other characteristics as it is shown in Figure Nº 2.2.1.

2.2.3 Quality and Quantity of the Supplement.

Digestibility The effect of supplementation on the digestibility is not clear. Arriaga-Jordan and Holmes (1986a) have shown a depression in digestibilty in the diet of cows supplemented with concentrate (-0.4%/kgDM concentrate). This was probably due to a reduction in gastrointestinal pH which resulted in a reduction in the digestibility of starch and cell wall carbohydrates (Reid et al,1980). However, Eldridge and Kat (1980) did not find that depression in digestibility in non-lactating cows supplemented with hay.

The form of the supplement can affect its digestibility. Pelleting and grinding increased the rate of passage reducing digestibility (Minson,1982; Shaver et al,1986). However, Raymond (1969) observed in high fibre supplements that grinding increased digestibility due to making the fibre structure more accessible to microbial attack.

Substitution rate The quality of the supplement can affect the substitution rate. Meijs (1986) compared a high starch supplement with a high fibre supplement for grazing dairy cows and concluded that the high starch supplement caused higher reduction in the consumption of pasture (0.45 kgDM/kgDM as concentrate) than the low starch supplement (0.21 kgDM/kgDM as concentrate). He suggested that change in substitution rate was related to the rumen fermentation, where the high starch concentrate tended to decrease the pH, affecting the cellulolytic activity of microbes (Vuuren et al,1985). Similar results were observed by Jennings and Holmes (1984) with concentrates of high or low quality. For hay supplementation, there is not much information related to the different quality. However, Stockdale et al (1981) and King and Stockdale (1981) suggested that the relative quality of hay compared with pasture determined the ability of the supplement to counteract the effects of underfeeding. It has been observed that the

amount of starch present in the faeces of cows supplemented with concentrate is increased (Stockdale et al,1987).

The relationship between quantity of supplement and substituition rate seems to be curvilinear (Bryant and Trigg,1982; Meijs and Hoekstra,1984; Stockdale and Trigg,1985). A similar relationship was reported for animal response by non-lactating cows (Saker and Holmes,1974) or by lactating cows (Meijs and Hoekstra,1984; Stockdale and Trigg,1985).

2.2.4 Physiological State.

Almost all the information available about supplementation on grazing cows is for lactating cows. There is not much information comparing non-lactating with lactating cows. However, it has been suggested by several authors (Moe et al,1971; Van Es,1975; Tyrrell,1980) that the partial efficiency of energy utilization for tissue gain is higher during lactation than during the dry period.

It is recognized that immediately after calving the appetite of the cow is such that the intake of energy is rarely able to match the high producing cow's requirement. Journet and Remond (1976) and Bines (1979) summarized several experiments and concluded that the length of time to reach the maximum appetite was largely dependant on the composition of the diet. However, in their reviews there were no data for diets for supplemented grazing cows.

Substitution Rate Information about the effect of stage of lactation on DM substitution rate is contradictory (Jennings and Holmes,1984; Phillips and Leaver,1985a;b).

Animal Performance Phillips and Leaver (1985a) and Stockdale et al (1987) reported a decrease in the milk yield per kgDM eaten as the lactation advance, however, this effect was not observed by Jennings and Holmes (1984) and Phillips and Leaver (1985b) supplementing with concentrate and silage respectively.

2.2.5 Other Factors.

There is not much information comparing the response to supplementation for different grazing systems. Arriaga-Jordan and Holmes (1986b) reported similar substitution rates and increases in animal performance for continuously stocked cows compared with strip grazing.

Kaufmann (1976) reported a higher response to supplementation with concentrates due to an increased frequency of feeding. He suggested that the effect was related to the maintenance of rumen pH (cellulolytic microbes).

It has been suggested that the season can affect the efficiency of utilization of the energy (Beever et al,1978; MacRae et al,1985; Cammell et al,1986), and consequently influence supplementation response.

2.3 VOLUNTARY FEED INTAKE.

Animal production is affected by the level of food intake and nutritive value of the feed (Dulphy et al,1980). Food intake and its variation is one of the major factors determining level and efficiency of animal production from pasture (Bines,1979; Hodgson,1982; Chase,1985; Leaver,1985). The control of food intake has been studied mainly under indoor feeding conditions,but it is assumed that the principles

developed from indoor experiments will apply to grazing animals with certain limitations (Arnold,1970). In addition, feed intake by grazing animals will also be affected by many other factors by which stall-fed animals are not affected.

Voluntary food intake for stall-fed animals is influenced by two main categories of factors : a) Factors which influence the animal's requirements for nutrients and its ability to metabolize absorbed nutrients (metabolic factors) and, b) factors which influence the animal's ability to consume the feed and accommodate and digest it in the digestive tract (physical factors) (Baumgardt,1970; Bines,1971). For grazing animals the inter-relationship between the metabolic, physical and behavioural factors determined the regulation of food intake (Hodgson,1977; Minson,1982).

2.3.1 Regulation of Food Intake.

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; Dulphy et al,1980; Baile and McLaughlin,1987). The animal attempts to maintain a constant energy balance by changing food intake in proportion to their altered physiological and environmental circumstances (Baile and Forbes,1974). The knowledge of the factors affecting regulation of intake and its mechanisms of control by ruminants are important to try to understand the relationships and response of the animals exposed to different environmental conditions.

For indoor feeding conditions the mechanisms controlling food intake are mainly associated with metabolic and physical factors

Metabolic Controls Physiological controls involve the potential feedback of the end products of digestion and metabolism to neural receptors in the brain (Chase,1985). The receptor sites for the feed back control system which inform the brain of 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; Annison et al,1982).

Glucose is not likely to be an important feedback signal in ruminants, as it is for non-ruminants (Baile and Mayer,1970; Bines,1971;Van Soest,1982). Propionate and acetate are recognized as possible signals of satiety in the ruminant (Baile and Mayer,1970). Butyrate is probably less important.The role of lactate is controversial, probably depressing the motility of the stomachs (Forbes,1980). A role of rumen pH as a physiological controller has been proposed by Kaufmann (1976), although, as with 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.

The role of hormones as signals of food intake is not clear. The possible role of hormones like estrogens, insulin, growth hormone, and others has been discussed by several authors (Forbes,1980; Wangness and Muller,1980; Baile et al,1983; Brockman and Laarveld,1986).

The importance of lipostatic mechanisms for long term regulation of energy balance is indicated by the negative correlation between body fat and feed intake (See Section 2.1.2). This mechanism attempts to maintain fat depots at a constant level once the animal has reached maturity but the system is not perfect (Freer,1981).

The role and importance of thermostatic control of intake under normal physiological conditions is unclear (Baile and Forbes,1974; Meijs,1981).

2.3.2 Physical Factors.

Ruminants fed bulky and fibrous feeds may stop eating before they have consumed sufficient nutrients to achieve their genetic potential for production (Campling,1970; Bines,1971,Meijs,1981), and a state of energy deficit will then prevail (Van Soest,1982). The physical limitation is related to:1) Distension of the Reticulo-Rumen(R-R), 2) Rate of disappearance of the R-R contents, 3) Others.

Distension of the Reticulo-Rumen Some evidence suggests that ruminants offered several roughages eat to a constant rumen fill (Campling,1970), although the rumen can be influenced by several conditions. For example, foetal enlargement and fat deposition within the abdominal cavity can reduce R-R capacity (Forbes,1980). There are stretch receptors in the rumen wall but the exact mechanism of transmission is not known. The probable mechanism can be by discomfort, by stimulation of the humoral intake regulating factor or by the mechanism of rumination (Van Soest,1982). The quantitative balance between rumen stretch and increase rate of passage remains unknown. The physical limitation of space in the gastrointestinal tract implies that volume rather than mass is important (Raymond,1969; Waldo,1986). Physical controls are primarily related to the capacity of the digestive tract (Freer,1981), the fiber content of the feeds and the rate of degradation and passage, therefore the 'indigestible' fraction of the DM is the major physical factor limiting intake (Minson,1982; Chase,1985).

The role of the gut fill as a mechanism of control of food intake is controversial and it has been associated with the type of diet. Some authors (Bines and Davey,1970;Lippke,1983) reported a limitation in gut capacity in cows fed mixed diets, but other authors (Waldo,1986; Grovum and Phillips cited by Minson,1982) considered that herbage intake is not limited by the capacity of the small or large intestines. Rumination, particle passage and nutrient absorption seem to be the limiting factors in the alleviation of 'fill' effect.

Physical limitations to the intake of forage cannot be overcome by supplementation, although improvement of poor quality diets with supplements (Protein,NPN) can alter the indigestible residue, by reducing the retention time and thus enabling forage intake to increase (Siebert and Hunter,1982).

Rate of Disappearance of the Reticulo-Rumen The rate of disappearance of the material from the R-R is dependent on the chemical composition of the feed, the degree of mastication and rumination, the rate of breakdown (microbial activity, motility of the rumen, fermentation conditions), the capacity of muscular contractions of the gut and the size of the reticulo-omasum orifice (Korver,1982; Ulyatt et al,1985). Retention of feed in the R-R allows substantial microbial fermentation to take place, with over 60% of OM digestion occuring in the R-R (Ulyatt et al,1985).

Two different processes are involved in the rate of disappearance:

a) Material which leaves the R-R by progressing down through the digestive tract.
b) Material which leaves the R-R as nutrients are absorbed through the gut wall (Bines,1971; Meijs,1981).

Dietary factors that influence ruminal retention time are:amount of feed consumed, forage physical form, forage:grain ratios, fiber content and physical nature of the fibre (Shaver et al 1986; Freer,1981). The physiological mechanisms of passage regulation are not clear (Ulyatt et al,1984).

Rate of passage Several factors have been suggested that are involved in the movement of particles from the R-R : size of particle, density of particles, rate of particle reduction, hydration time, cell wall content, pH and osmotic pressure, strength and frequency of ruminal and/or abomasal contractions and consistency of digesta (Shaver et al,1986; Martz and Belyea,1986).

Undigested material can escape through the reticulo-omasal orifice only after being reduced into fine particles (<2.0 mm). The particle size is relatively insensitive to changes in digestibility, physical form of the diet, intake, type of pasture or the liveweight of the animal (Ulyatt et al,1985). The latter authors suggested that the amount of material passed per contraction of the reticulum is probably more important than the particle size. The understanding of this process is .not clear. Digesta load would be expected to change rate of removal of OM, not only affecting the rate of digestion, but also by influencing rumination and propulsive activity (Weston,1982). Particle size reduction begins with prehension and initial mastication of the forage. Total time spent chewing is influenced by ration quality.

2.3.3 Behavioural Factors.

The behavioural factors play a key role in the mechanisms of control of the grazing animals. The total amount of food eaten by an animal in a given period of time depends on: the number of bites in that time (rate of biting for grazing animals), the grazing time and, the intake per bite (Allden and Whittaker,1970; Bines,1971).

The behavioural control of intake is related with the prehension of the feed by the grazing animal (Allden and Whittaker,1970; Hodgson,1977), opportunity for selection, herbage preference and type of feed. The amount of herbage prehended per bite 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 rate of biting or grazing time are usually limited, it is likely to be a major determinant of daily herbage intake (Leaver,1985; Hodgson,1985b).

The grazing time 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) falls steadily with increasing proximity of the grazed horizon to the ground level (Hodgson,1977).

Herbage Allowance The amount of herbage prehended per bite appears to be the component of ingestive behaviour most sensitive to variations in sward conditions (Allden and Whittaker,1970; Hodgson,1976;1985b). The compensatory changes in rate of biting and grazing time are limited. Grazing time increased as herbage allowance decreased to about 32 kgDM/cow/day for lactating dairy cows during the summer (Stockdale and King,1983b), and 22.5 kgDM/cow/day during the

winter (LeDu et al,1979). But as herbage allowance decreased further, grazing time was also decreased. In the U.K., Zoby and Holmes (1983) reported higher grazing times, rate of biting or number of bites per day for cows stocked 12 cows/ha than for 6 cows/ha during the spring,but not during the summer. At low allowances, calves did not increase their grazing time to try to compensate for bite size (Jamieson and Hodgson,1979). Stobbs (1974), suggested that rate of biting provided a valuable guide to the relative ease with which herbage is harvested from tropical pasture swards. Mean rates of biting were not different across allowances (LeDu et al,1979; Jamieson and Hodgson,1979), but the interaction between time of the day and allowance was significant.

Effect of Supplementation Several authors have reported a reduction in grazing time between 9-38 minutes/kg DM for grazing cows supplemented with concentrates (Sarker and Holmes,1974; Journet and Demarquilly,1979; Arriaga-Jordan and Holmes,1986b), silage (Phillips and Leaver,1985b), or hay (Phillips and Leaver,1985a).

Rumination time is related to the cell wall content of the food (Van Soest,1982). Lower rumination time was found for a pellet hay compared with long or chopped hay (Shaver et al,1986). Rumination time was significantly increased by offering hay or silage to grazing cows (Phillips and Leaver,1985a,b).

2.4 FACTORS AFFECTING FOOD INTAKE BY GRAZING ANIMALS.

2.4.1 Animal Characteristics and Environmental Factors.

Voluntary feed intake is set by the animal's potential requirement for dietary energy. The environmental factors affecting herbage intake have been recently reviewed by Weston (1982).

2.4.2 Animal Size, Liveweight, Body Condition, Age and Genotype.

The size of the animal is critical in determining the volume of the abdominal cavity,which is related to rumen capacity (volumetric expansion) during eating (Bines,1976,1979; Meijs,1981).The correlation between size and liveweight is high for growing animals (Rohr cited by Meijs,1981).However, for adult animals liveweight could be an imprecise scaler with respect to body size (Weston,1982), because of gut fill or fat content. Although it is generally reported that the heavier animal eats more (Bines,1976,1979; Meijs,1981; Schwarz and Kirchgessner,1985).

In early lactation,liveweight change is the result of a predetermined level of food intake and of the current level of milk production, not its cause (Bines,1979).

Intake is related to body condition (Bines,1976; Forbes,1980; Broster and Thomas,1981; Grainger and McGowan,1982; Allison,1985). Fat cows at calving ate less than thin cows (see Section 2.1.2). The age of the animal is usually confounded with the previous factors or with the

physiological state of the animal,although heifers ate less in comparison with adult cows on the basis of comparable liveweight (Schwarz and Kirchgessner,1985), probably related to abdominal capacity.

The genetic basis of variation in voluntary herbage intake is difficult to establish in grazing cows, because of difficulties in measurement of intake (Fulkerson et al,1985). Several authors have been reported differences between breeds (Weston,1982), and within breeds (Bryant,1985). For grazing cows, low breeding index cows (LBI) ate less feed (6-20%) during part of the lactation than the high breeding index cows (HBI) (Holmes and MacMillan,1982). Bryant (1981) and Mitchell (1985) suggested that HBI cows graze more efficiently than the LBI cows when pasture was restricted. Grainger (1982) have shown that HBI cows ate similar quantities of feed to LBI cows during the dry period. There was no difference in energy metabolism between cows of LBI and HBI (Trigg and Parr,1981; Trigg et al,1982).

2.4.3 Effect of Lactation.

Lactating cows consumed more food than non-lactating cows (Hutton,1963; Leaver et al,1968; Bines,1976; Hodgson,1977;Shaver et al,1986). This effect was not influenced by the type of diet. On average lactating cows consumed 42% more than the non-lactating cows,although in some reports the effect of pregnancy was confounded. Considering that the lactating cow has higher physiological requirements, it has been suggested that the greater intake appears to be due to hypertrophy of the alimentary tract (Tulloh cited by Meijs,1981; Leaver,1985), or hormonal differences (Freer,1981).

There is an increase in food intake between first and fourth lactation (Bines,1979; Journet et al cited by Neal et al,1984), but most of it occured between the first and the second lactation (Journet and Demarquilly,1979). However, that increase can be affected by the size and age of the cows. Several authors have reported an increase in intake associated with the level of milk production (Bines et al,1977,1979; Vadiveloo and Holmes,1979; ARC,1980; MAFF,1984).

Immediately after parturition milk production rises rapidly 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 whose reasons are incompletely established (Meijs,1981). It has been suggested that the factors are of physical origin (Bines,1976), abdominal fat (Journet and Remond,1976), delay of hypertrophy of gut wall,liver (Bines,1979), alimentary tract (Tulloh cited by Meijs,1981), or endocrinological factors.

2.4.4 Effect of Pregnancy.

Meijs (1981) suggested that the effect of pregnancy is commonly confounded with the effects of lactation or animal growth. During pregnancy the volume and nutrient demand of the foetus progressively increased,reaching an important role in the energy status of the cow during the last three months of gestation (ARC,1980; Weston,1982). It is generally accepted that the intake falls as parturition approaches regardless of the type of diet offered (Forbes,1971; Journet and Remond,1976; Meijs,1981; Weston,1982). A decline of 0. 2 kgDM/week during the last 6 weeks of pregnancy was found by Journet and Remond,1976. The possible reasons suggested for the decline in intake are: A reduction in volume of the abdominal cavity due to physical compression of the uterus on

the rumen (Forbes,1971; Baile and Forbes,1974; Bines,1979), and/or abdominal fat (Weston,1982), endocrine changes for example the increase in placental secretion of oestrogens (Forbes,1971).

2.5 SWARD CHARACTERISTICS.

The effect of sward characteristics affecting herbage intake has been reviewed in detail (Hodgson,1976; 1982; 1984; Leaver,1976; 1985; Hudges,1983; Holmes,1987). For the grazing animal the importance of the metabolic, physical and behavioural control of the herbage intake and its interrelations depends on the nutritional and non-nutritional characteristics of the sward (Hodgson et al,1985) The herbage intake under grazing conditions is seldom affected by metabolic limits (Hodgson,1977) for high producing cows. However, its influence is more important for non-lactating grazing cows.

2.5.1 Diet Selection.

Grazing cows exhibit diet selection through choice of grazing site and then the bite within the site (Hodgson,1982; Poppi et al,1987). Grazing site is influenced by plant species, stage of maturity and distribution of green material, dung, urine and/or soil contamination. The bite site is driven by the preference for pasture species or plant parts and it is probably controlled by physical effects (difference in strength), due to taste, smell or odors (Baile and Forbes,1974; Freer,1981). The selection is sometimes confounded with the availability and opportunity for selection of these components in the sward (Hodgson,1982). The animal eats more leaf than stem, more green than dead material, temperate than tropical grasses, more legumes than grasses (Baker,1976; Minson,1981;

Poppi et al,1981; Rogers et al,1982). However, those relationships can be changed by experience (Arnold,1970). Diet selection influences the digestibility of the diet eaten compared with the pasture on offer and affects bite size (Poppi et al,1987).

2.5.2 Nutritive Value.

The intrinsic quality of a sward will be determined by the species present, stage of growth, soil type and management imposed upon it (Baker,1976). When crude protein content in the feed falls below 6-8%, the appetite of the animal will be depressed by a deficiency of protein and food intake will be less than might be expected (Minson,1982). Herbage intake is also influenced by the cell wall content of the material (Van Soest,1982) or the deficiency of other nutrients such as minerals (VanEs,1983).

As a general principle digestibility is a satisfactory way of examining nutritive value and its influence on the amount of feed required by an animal (Hodgson,1977; Poppi,1983). Digestibility is a major determinant of pasture quality, 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, the relationship is imprecise and it is not a good predictor. The intrinsic characteristics of plants which determine digestibility are not necessarily the same as those affecting herbage intake (Leaver,1976). The differences in animal response are related to the differences in the site of digestion of the protein and organic matter (Poppi,1983). It seems that the effect of digestibility on herbage intake is related to rate of passage.

The factors affecting the digestibility has been reviewed in detail (Raymond,1969; Reid et al,1980; Minson,1981;1982). The effects of declining intake and digestibility upon nutrient intake is additive (Hodgson,1979b).

2.5.3 Sward Density and Herbage Height.

In the range of values for bulk density commonly found in temperate pastures, herbage intake appears to be insensitive to changes in bulk density in the grazed horizon (Hodgson,1981). Although the size of individual mouthfuls of herbage tends to fall once the density of material in the sward horizon of a sward falls below 25 kgDM/ha/cm (Stobbs,1973; Hodgson,1979b).

Hodgson (1977) suggested an asymptotic relationship between herbage height and herbage intake, for set-stocking cows. The higher herbage intake associated with increasing height, appears to be related to to an increased size of bite (Hodgson,1982). The height to which grass is grazed, is frequently used to estimate the amount of herbage available for continuous grazing animals, and for break-grazed cows.

2.5.4 Herbage Mass.

The incremental increase in intake or animal performance per unit of herbage mass declines rapidly following the law of diminishing returns as herbage mass increases (Hudges,1983; Hodgson,1984). The relationship between herbage mass and herbage intake has been reported to be asymptotic (Hodgson,1977;1979; Combellas and Hodgson,1979; Hodgson and Jamieson,1981; Meijs,1982). However, Meijs (1981) and Stockdale (1985) did not find these results. The latter authors suggested that the decline is probably related to

decreases in herbage quality which are usually associated with increases in herbage mass.

Intake per bite has been shown to decrease as herbage mass declined for sheep and cattle (Allden and Whittaker,1970; Jamieson,1975; Chacon et al,1976; Forbes and Hodgson,1985). The mechanisms of behavioural compensation (increased grazing time or rate of biting) for a decline in intake per bite are not enough to maintain total intake (Chacon et al,1976; Jamieson and Hodgson,1979; Hodgson,1981).

2.5.5 Herbage Allowance.

Herbage allowance (DHA) has been shown to be an important determinant of the herbage intake and consequently of the animal performance of lactating dairy cows (Combellas and Hodgson,1979; LeDu et al,1979; Bryant,1980; Glassey et al,1980; King and Stockdale,1984; Mitchell,1985; Stockdale,1985) or non-lactating cows (Nottingham,1978; Holmes and McClenaghan,1980; Ngarmsak,1982). It has been used for rotational grazing systems. It is not applicable to set-stocking systems.

The relationship between DHA and herbage intake, and between DHA and animal performance have been proposed to be asymptotic (Greenhalgh et al,1975; Combellas and Hodgson,1979; Bryant,1980). Herbage OM intake approaches maximum at an allowance 4 times greater than the amount actually eaten (Hodgson,1976), but only starts to decline markedly when DHA is less than twice intake for lactating cows (LeDu et al,1979). Grazing time increased as DHA decreased to about 32 kgDM/cow/day but as DHA decreased further grazing time also decreased (Stockdale and King,1983) for lactating cows.

Associated with increase in DHA is an increase in residual herbage mass (RHM), and DHA or RHM can be used to indicate herbage intake (LeDu et al,1979; King and Stockdale,1984; Holmes,1987).

The limiting factor concerning DHA and its effect on herbage intake is the height of the residue left after grazing, but height of the residue can vary widely, for the same DHA and DM intake, depending on the pregrazing herbage mass (Grainger et al,1982; Leaver,1986). Although, behavioural factors probably limited the intake at low allowances (Hodgson,1977; Meijs,1981). The effect of DHA can be affected by pasture species (Stockdale,1985), herbage mass (Combellas and Hodgson,1979), season (Holmes,1987) and quality (Hoogendorn,1987). To avoid part of that variability Butler et al (1987) suggested that DHA should be expressed in terms of green leaf.

Herbage production may be relatively insensitive, within certain limits, to variations in DHA or RHM in established swards (Hodgson,1984). Although the influence on botanical composition are of potential importance (Holmes and Hoogendoorn,1985).

2.6 WATER CONSUMPTION.

Water is one of the most important nutrients for dairy cows (Nicholson,1985). Its main fuctions are: act as a solvent (transport), as a cooling agent (due to its high heat capacity, high thermal conductivity and high latent heat of vaporization), as a lubricant, also the movement of energy between and within the organisms of an ecosystem is related to or dependant on water (MacFarlane and Howard,1970; More and Sahli,1981; Lanham et al,1986).

The water requirements of cattle are met from: water consumed voluntarily, water contained in feed and on feed, water formed within the animals as a result of metabolic oxidation and water in inspired air (Leitch and Thomson,1944; Nicholson,1985). The practical importance of water from oxidation for the general balance of the cow is not easy to relate with the water input.

The major avenues of water loss from body are: faeces, urine, evaporation from the lungs and skin and animal products (milk). In temperate conditions where the loss by evaporation is not as critical as in tropical conditions, the main need for water is to meet physiological conditions.

The homeostatic control of body water content is dependent on a regulated balance of hormonal and neural mechanisms. It depends on a sensitive regulation of the Antidiuretic hormone (avoid overhydration) from the neurohypophysis and on an efficient thirst mechanism that ensures that water loss is compensated by drinking (Andersson,1978; Olsson and Kinley,1980; Rolls and Rolls,1982).

The role of the rumen as a water "reservoir" is a general characteristic of ruminants (Andersson and Olsson,1970; Shkolnik et al,1980). It has been suggested that any changes in the rumen medium are likely to alter the fermentation pattern and in turn the function of the rumen (More and Sahni,1981). However, Andersson (1985) reported that low water temperature can depress microbial activity in the rumen.

Drinking Water The main method for replacing water lost is by drinking, although water in and on plants may be an important source. In New Zealand, Wright and Jones (1974) reported that drinking water was equivalent to 30% of the total water consumed, while a corresponding value of 18% was reported by Castle and Watson (1973) in the U.K. An important factor

involved in the water balance is water turnover or the proportion of water utilized in a given unit of time (Nicholson,1985).

It has been suggested that there are 2 types of drinking. Primary drinking, in which the consumption of water is developed when relative or an absolute lack of body water is present (Andersson,1978); and secondary drinking in which the consumption of water is developed when there is no internal need for water (e.g. Dry mouth).

Water intake is affected by: animal factors such as age, sex, size, metabolism, physiological condition of the animal, performance, body water content, activity, breeds (between and within); environmental factors such as season, air temperature, rainfall (Castle and Watson,1973; Cowan et al,1978), relative humidity, solar radiation, wind, quality, quantity and temperature of the water; nutritional factors such as diet (quality, type or form), feed intake, and animal management factors such as type of housing (Campbell,1958; Payne,1966; MacFarlane and Howard,1970; Castle,1972; Castle and Watson,1973; Wright and Jones,1974; Cowan et al,1978; Odwongo,1983; Nicholson,1985). Any factor that affects water turnover will influence the drinking requirements of the animal or viceversa.

Some of those factors are discussed briefly:

Body Content Water comprises between 60 - 80% of total body weight. However, this is affected by several factors. One of them is the body composition, thus fat cows may have less than 50% and thin as much as 70% of water of the total body weight (Reid et al cited by ARC,1980).

Physiological State Physiological state and state of growth affect water intake. Benlamlih et al (1985) working with goats suggested that the change in water intake associated with

pregnancy was related to hormonal changes (Placental lactogen). The relationship between size, production and drinking capacity was far from perfect for grazing cows (Campbell,1958). Water turnover is generally accepted to be slower in dry cows than for lactating cows (Wright and Jones,1974; Cowan et al,1978; Woodford et al,1984), suggesting that it is related to milk production and the increase in food intake. Water drunk by lactating cows was positively and significantly related to the mean daily milk yield and the DM content of the ration (Cowan et al,1978; Murphy et al,1983).

Food Intake Payne (1966) suggested that drinking large volumes of water had no effect on food intake. Increasing intakes of food intake are generally associated with increasing voluntary water intake (ARC,1980; More and Sahni,1981; Murphy et al,1983; Stockdale and King,1983).

The role of food intake in relation to water intake is associated with its role as a water source and by the linkage between food intake and water intake especially during water restrictions. It is recognized that water restrictions reduce food intake (Leitch and Thomson,1944; More and Sahni,1981). There is a biological linkage between the turnover of energy and the control of water (hypothalamic region).

Type of Feed More and Sahni (1981) summarized the correlations between hay intake and water intake, and concluded that the relationship is high and positive. High protein content of the food is associated with high water intake (More and Sahni,1981; Benlamlih et al,1985), since the nitrogenous end-products require a larger urine volume for excretion (ARC,1980).

Water to feed ratio is affected by air temperature (Richards,1985), water temperature (Brod et al,1982; Andersson,1985), water availability (Little et al,1978; King and Stockdale,1983), animal performance, days of gestation, type of food and amount of salt eaten (ARC,1980).

The type of forage determines the frequency of drinking (silage 3.3 times vs 7.0 dried grass (Castle and Thomas,1975). When water is freely available, grazing cows usually drink 1 - 5 times daily, but probably no more than 7 (Hancock,1954; Campbell,1958).

Water Characteristics The quality of drinking water can affect livestock production due to the amount of total dissolved salts, toxic or contaminating substances and disease producing mechanisms (Nicholson,1985).

Water temperature can affect animal performance not only affecting the rumen media, but also the thermoregulatory status of the animal. Rumination time seemed to increase with warmer water (Andersson,1985).

Water availability The restriction of drinking water from free choice to once or twice per day has not shown significant effects on milk yield for lactating cows (Campbell,1958; Castle and Watson,1973; King and Stockdale,1981b). However, Little et al (1978) observed a reduction in milk yield (24%) and food intake (16%) when lactating cows were restricted to 40% of the quantity of water drunk by cows with ad libitum access to water.

2.7 OBJECTIVES OF THE STUDY.

Hay has been used extensively in New Zealand as a winter supplement. However, there is a lack of knowledge of the effects of hay supplementation not only on animal intake and performance, but also on the effects on the sward characteristics. Any previous research, when has been done with hay supplementation has been done mainly for lactating cows, with limited information for non-lactating, pregnant cows.

The present study was designed to assess the effect of hay supplementation at two different herbage allowances during the winter for non-lactating cows on: the pasture intake, residual herbage mass, total DM and ME intake, water consumption and its effect on gains in liveweight and body condition score.

CHAPTER 3

3 MATERIALS AND METHODS

The experiment was conducted for 42 days during June and July 1986, at Massey University Dairy Research Unit, Palmerston North, New Zealand.

The unit is a seasonal supply farm, divided into paddocks of approx. 0.8 ha. The type of soil is a clay-soil Tokomaru silt loam, which has been drained with tiles and moles.The paddocks of the whole unit were fertilized with 350kg of potassic superphosphate per hectare per year and 50-100kg urea/ha/year. The surpluses of grass during the year are conserved as silage (early conservation) or hay (late conservation).

The meteorological data during the experimental period were collected in the D.S.I.R. grassland division.

The common abbreviation utilized during the experiment are shown in Table Nº 3.1.

Table Nº3.1 Common Abbreviations

B.C.	Body Condition
DHA	Daily Herbage Allowance
DM	Dry Matter
DMD	Dry Matter Digestibility
DOMD	Digestibility of Organic Matter of the DM
GE	Gross Energy
$-_h$	Of the Hay
HA	High Herbage Allowance
HA+	High Herbage Allowance plus Hay
HM	Herbage Mass
I	Intake
IB	Intake per Bite
LA	Low Herbage Allowance
LA+	Low Herbage Allowance plus Hay
ME	Metabolizable Energy Content
MEI	Metabolizable Energy Intake
OMD	Organic Matter Digestibility
$-_p$	Of the Pasture
Prot	Protein Content
q	Metabolizability
RB	Rate of Biting
SEM	Standard error of the mean
RHM	Residual Herbage Mass

3.1 GENERAL PRE-EXPERIMENTAL CONDITIONS

3.1.1 Pastures and Hay.

The pastures utilized during the experiment consisted mainly of perennial ryegrass (Lolium perenne) and white clover (Trifolium repens), with a small proportion of cocksfoot (Dactylis glomerata), phalaris (Phalaris spp.) and prairie grass (Bromus catharticus).

The hay was produced in the farm from swards of similar botanical composition.

The area used to run the experiment was 5.1 ha. It consisted of six paddocks, which were mole-drained recently (1-2.5 years).

3.1.2 Animals and Treatments.

24 pregnant, non-lactating cows that had completed 2 or more lactations were randomly distributed to four experimental groups. Details of the pre-experimental age, days of gestation, fasted liveweight and body condition score are reported in Table Nº 3.1.1.

Table Nº 3.1.1. Pre-experimental age, days of gestation, fasted liveweight and body condition score of the animals allocated to the different treatments.

	TREATMENTS			
	L.A.	L.A.+	H.A.	H.A.+
Age (Years)	6.5	6.7	6.2	6.5
±S.E.M.	(0.8)	(0.8)	(0.7)	(0.8)
Days of gestation	217	204	198	210
±S.E.M.	(2.0)	(8.0)	(6.0)	(7.0)
Liveweight(kg)	481	497	497	485
±S.E.M.	15.8	24.5	26.2	20.0
Body Condition(Score)	5.3	5.2	5.0	5.2
±S.E.M.	0.5	0.3	0.4	0.2

Means within the same line are not significantly different($P<0.05$).

The four groups were defined:

1. Low daily herbage allowance (LA)

2. Low daily herbage allowance plus hay (LA+)

3. High daily herbage allowance (HA)

4. High daily herbage allowance plus hay (HA+)

Additional to those treatments was conducted another group of cows of similar characteristics which was allocated to very low herbage allowance (5 kgDM/cow/day) and supplemented with hay (5KgDM). These animals were withdrawn from the experiment after one week, because of difficulties in the management and severe damage of the paddocks by treadings.

Details of the pasture DM and hay planned to offered to the different treatments are shown in Table Nº 3.1.2.

Table Nº 3.1.2.Details of the pasture DM and hay planned to offered to the different treatments.

	LA	LA+	HA	HA+
Herbage Allowance (kgDM/cow/day)	9	9	14	14
Hay Offered (kgDM/cow/day)	0	5	0	5

The amount of hay offered was adjusted weekly depending on the moisture content.

The LA diet was planned to satisfy the cow's requirements for maintenance and pregnancy (ARC, 1980).The estimated intake assumed was the values reported by Holmes and McClenaghan (1979), with similar type of grasses, but with lighter animals.

The LA+ and HA treatments were designed to reach similar levels of DM intake.

Management Sward and Animals. The cows were offered one new strip of fresh pasture each day in the morning.Each break was backfenced not only to prevent the cows from having access to the preceeding pasture offered, but also to prevent damage by pugging.

The hay supplement was offered in troughs, after the new break of pasture was offered. All the hay offered during the experimental period was eaten. On one day during the experiment, due to extreme weather conditions, the animals were taken out of the paddock and relocated in a dry area, where the DM allowance was offered as hay.

The animals were given continuous access to water in troughs.

3.2 MEASUREMENTS.

3.2.1 Pasture.

The pasture was cut before and after grazing on 19 occasions (Walters and Evans, 1979) during the whole experiment. On each occasion 5 quadrats (0.1875m^2 each) were cut to ground level for each treatment. Simultaneously, another 5 samples per treatment were cut at around 4 cms. above ground for chemical analysis.A sheep shearing hand piece powered by a mobile petrol generator was used to cut the herbage.This operation was always made by the same operator, to prevent the variability associated with the technique (Thomson, 1986).

After cutting, the samples cut to ground level were washed to remove soil contamination and dried at 70-80°C for 36 hours.Herbage mass, kgDM/ha, was subsequently calculated from the data.

The samples cut at 4cms above ground level were dried at 70 -80°C for 72 hours, then ground and passed through a 2mm. sieve.Those samples were subjected to analyses for:

a)Gross energy Concentration-kj/kg-
(Adiabatic Calorimeter Bomb),
b)Nitrogen Concentration-g/kg- (Kjendahl),
c)Ash concentration-g/kg- (500°C/24hours),
d)in vitro digestibility (Roughan and Holland,1977).

The measured pregrazing herbage mass was used, together with the required daily herbage allowances, to calculate the areas of pasture to be grazed by the four groups of cows. The width of the paddocks was always fixed (Proportional to the allowance). The daily length of the break was the adjustable measure.

3.2.2 Hay.

Samples were taken daily from the hay offered to each of the supplemented groups.Those samples were bulked within each paddock. After mixing, drying, grinding and passing through a 2mm.sieve, the samples were sent to the laboratory to carry the same analysis previously described for the pasture.

In vivo Digestibility of Hay The in vivo digestibility of the hay offered was evaluated using 4 sheep. Liveweight of the animals was 37±2Kg at the start of the digestibility period. The level of nutrition was planned to be at maintenance. The animals were allowed to become accustomed to the hay as a sole

diet for 14 days pre-experimental period before collection of the data began. The experimental time lasted 14 days. The hay offered and refused, and the faeces were weighed daily;the faeces and the refusal were bulked and stored at -4°C. Samples of the faeces, hay offered and refused for each of the animals were dried at 70 - 80°C for 48 hours, and then subjected to laboratory analysis, as described previously for the pasture.

Calculations

$$DMD\% = \frac{DM\ offered - DM\ refused - DM\ faeces}{DM\ offered - DM\ refused} \times 100$$

$$OMD\% = \frac{OM\ offered - OM\ refused - OM\ faeces}{OM\ offered - OM\ refused} \times 100$$

$$DE\ \% = \frac{GE\ offered - GE\ refused - GE\ faeces}{GE\ offered - GE\ refused} \times 100$$

$$PROTD\% = \frac{PROT\ offered - PROT\ refused - PROT\ faeces}{PROT\ offered - PROT\ refused} \times 100$$

In vitro Digestibility of the Feeds The in vitro digestibility was measured using the technique described by Roughan and Holland (1977). The values reported were DMD, DOM and DOMD.The metabolizability of the diet was defined as the proportion of ME/GE (ARC, 1980), and was calculated assuming that the DOMD was the digestibility of the energy (Holmes and Wilson, 1984) and that the metabolizable energy was considered 81% of the calculated digestible energy (MAFF, 1984).

3.2.3 Sward Measurements.

Daily herbage allowance, pregrazing herbage mass, residual herbage mass and degree of defoliation were used as defined by Hodgson (1979). The daily metabolizable allowance was defined as the total ME offered in the diet to the cows, expressed in MJME/cow/day.

Apparent herbage intake was estimated as the difference between the pregrazing herbage mass and the residual herbage mass, multiplied by the area allocated daily divided by the number of cows grazing during that time.It was expressed as kg/cow/day of fresh matter, kg DM/cow/day for dry matter and MJME/cow/day for metabolizable energy. The concentration of DM in the diet was calculated as the apparent DM intake (gr.) when a kg of fresh matter was consumed. (gr.DM/kg) Substitution rate was defined as the change (units) in intake of pasture when the animal consumed one unit of hay.It was expressed in dry matter (kg DM) or metabolizable energy (MJME.).

Calculations of the Metabolizable Energy For the supplemented diets, it was assumed that the digestibilities of the two feeds were independent, and that there was no interaction as reported by Eldridge and Kat (1980); Corbett (1978). The values used for the different digestibilities were the in vitro calculated ones.

$$\text{metabolizability}(q) = 0.81 * \text{DOMD}$$

$$\text{ME(MJ/cow/day)} = \frac{GE_p * q_p * DMI_p + GE_h * q_h * I_h}{\text{Total apparent DMI.}}$$

See Table Nº 3.1.

3.2.4 Animal Measurements.

Liveweight The cows were weighed on two consecutive days immediately prior to the start of the experiment and on two days commencing 48 hours after the experiment.Cows were fasted for 18 hours prior to weighing to avoid a confounding effect by gut-fill.The 48 hours interval between the termination of the experimental period and the final weighing was to minimize the effect of possible gut fill differences between treatments. The values of the two consecutive days was averaged, except for one cow in the HA treatment that aborted prior to the final weighing day.

The unfasted liveweight of the cows was corrected using the ARC (1980) regression equation to calculate the estimated weight of the gravid uterus, assuming that the weight of the calf at calving would be approximately 40 kg. These values are reported as the net cow's liveweight. The net liveweight gain was defined as the difference in net liveweight between the start and the end of the experiment, previously corrected by the estimated weight of the gravid uterus. The requirements for maintenance of the cows were calculated using the methodology reported by Hutton (1962).

Body Condition Body condition score for each cow was assessed at the same time as the liveweight. The score system utilized was that reported for Scott et al (1980), with a range of 1-10. The scores of the two consecutive days were averaged.

3.2.5 Water Measurements.

The quantities of water drunk each day were calculated from the quantities which disappeared from the water troughs after correction for rainfall and evaporation (See Table Nº 4.2.5). Water was measured at least three times per day.

The total apparent water intake was estimated as the water drunk voluntarily plus the water ingested in the feed eaten (ARC,1980). Water ingested with the food was assumed to be the content of water within and on the feed, and was determined as the moisture content of the sample.

Calculations

$$\text{Apparent total Water Intake(lts)} = \text{Water drunk} + \frac{(\text{Total DMI} * \text{moisture content})}{\text{DM content}}$$

3.2.6 Animal Behaviour.

The behavior of the animals allocated to the different groups was evaluated during two consecutive days on three occassions (a total of six days).

The rate of biting of each individual was measured each 30 minutes during the first three hours after the cows received the new grass break, using the 20-bite technique (Hodgson,1982a; Jamieson and Hogdson,1979). During four of the six days, the herbage mass was estimated for each treatment group at intervals of 30 minutes during the period of 2 hours after the cows began to graze the new areas of pasture. A

rising plate meter was used for these estimations of herbage mass (Holmes,1974), from which the rate at which herbage was apparently consumed could be calculated. The meter was previously calibrated with herbage cuttings to ground level, and then data were regressed.

The behavioral activity was measured during the daylight time over 8 days. The events observed were divided into: grazing, eating hay, ruminating, drinking or idling. The resting, standing, and idling were reported as idling. If the activity was not clear when the animals were observed, it was allowed 20 seconds to equilibrate before its activity was reported. The observation were compiled each 30 minutes during the first three hours the cows were offered the new strip of grass, and after that each 15 minutes. The activity recorded at one observation assumed to continue until the next observation. Observations ceased when it was not possible to distinguish the eartag identification of the cows.

3.3 STATISTICAL ANALYSIS.

The experimental design was a 2X2 factorial. All data was analyzed using the Statistical Analysis System (SAS) computing package (SAS Institute, 1985).

Analysis of percentages were conducted on untransformed data, after a test of normality of the distribution (Steel and Torrie,1982).

The model used to define the data was:

$$Y_{ijk}=\mu + a_i + c_j + (ac)_{ij} + \varepsilon_{ij}$$

where

Y_{ijk}=The observation on the k^{th} individual exposed to the i^{th} herbage allowance and the j^{th} hay supplementation.

μ=The unknow population mean.

a_i=The effect of the i^{th} herbage allowance
i=1, 2

c_j=The effect of the j^{th} hay supplementation
j=1, 2

$(ac)_{ij}$=Effect of the interaction between the i^{th} herbage allowance and the j^{th} hay supplementation.

ε_{ijk}=The random error associated with the k^{th} individual exposed to the i^{th} herbage allowance in the j^{th} hay supplementation.It is assumed that ε_{ijk} is normally distributed with mean 0 and and variance σ^2.

Sward (HM, RHM,DHA), intake (DMI, MEI, substitution rate of the DM and ME), water(Water drunk, total water consumed) liveweight and body condition gains and the behavioral (RB, IB) data were analyzed using analysis of variance (Steel and Torrie, 1982).

Liveweight and body condition score were analyzed using the following model:

$$Y_{ijk}=\mu + a_i + c_j + (ac)_{ij} + \beta X_{ij} + \varepsilon_{ijk}$$

where

Y_{ijk}=The observation on the k^{th} individual exposed to the i^{th} herbage allowance and the j^{th} hay supplementation.

μ=The unknow population mean.

a_i=The effect of the i^{th} herbage allowance
i=1, 2

c_j=The effect of the j^{th} hay supplementation
j=1, 2

$(ac)_{ij}$=Effect of the interaction between the i^{th} herbage allowance and the j^{th} hay supplementation.

β=Regression Coefficient associated with X_{ij}.

X_{ij}=Pre-experimental condition of score or liveweight of the j^{th} cow exposed to the i^{th} treatment.

ε_{ijk}=The random error associated with the k^{th} individual exposed to the i^{th} herbage allowance in the j^{th} hay supplementation.It is assumed that ε_{ijk} is normally distributed with mean 0 and and variance σ^2.

Actual significance levels are presented in the results and unless otherwise stated a critical significance level of 5% has been taken.

Some regression analysis were carried, but the major limitation to develop those results were the kind of information compiled, some of the information was individually (liveweight, body condition, etc.), and some was group information (herbage intake, water drunk, etc..).

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

CHAPTER 4

4 RESULTS

4.1 SWARD CHARACTERISTICS.

4.1.1 Pregrazing Conditions.

There was little variation in pregrazing herbage mass between the six paddocks 2733 ± 44 kg/ha (Table Nº4.1.1.). However, the pregrazing herbage mass of the areas allocated to the low allowance groups was significantly greater than those of the high allowance ($P<0.05$). This difference was apparently due to chance. The dry matter concentration of the pasture during the experimental period was 15.1% (±0.2). The dry matter concentration of the hay offered to the cows was 83.0% (±0.02).

Table Nº4.1.1.Mean values and results of ANOVA for the quantities of Pregrazing Herbage Mass(KgDM/ha) and Concentration of the Dry Matter(%) for the four treatments.

	TREATMENTS				Sig.Level		
Paddock Nº	L.A.	L.A.+	H.A.	H.A.+	$\pm SE_{LSM}$	DHA	HAY[1]
1	2955	2817	2657	2783			
2	2411	2765	2522	2486			
3	3063	3171	2981	2697			
4	2658	2527	2613	2310			
5	3272	3114	2859	3100			
6	2684	2352	2186	2130			
MEAN	2862	2808	2640	2620	85	*	NS
DM Concentration (%)	14.6	15.3	15.4	14.9	0.45	NS	NS

NS:Not significant(P>0.05). The symbols (*), (**) and (***) indicate the significance levels of P<0.05, P<0.01 and P<0.001, respectively. [1] The interaction between herbage allowance and the level of hay supplementation was not significant (P>0.05).

The daily quantities of herbage allowance, hay and total DM offered to the different groups are shown in Table Nº 4.1.2.The quantities of total DM offered to the LA+ and HA treatments was similar, although the energy offered was different, because of the differences in quality between the two diets.

Table Nº4.1.2. Mean values and results of ANOVA for the quantities of Herbage Allowance, Hay, and Total DM offered per cow daily (KgDM/cow/day) for the four treatments.

DM Allowance	TREATMENTS L.A.	L.A.+	H.A.	H.A.+	$\pm SE_{LSM}$	Sig.Level DHA	HAY[1]
As Herbage	9.2	9.1	13.4	13.4	0.32	***	NS
As Hay	0.0	5.0	0.0	5.0			
Total	9.2	14.1	13.4	18.4	0.32	***	***

[1] See footnote for Table º4.1.1.

The stocking density for the low and high allowance was of 311 and 191 cows/day/ha respectively.

The in vivo dry matter digestibility (D.M.D.) of the hay was 56.2% (±0.01) (Table Nº4.1.3) and the in vitro dry matter digestibility was 58.5% (±1.0). The in vitro dry matter digestibility of the pasture was 77.9% (±0.15). There was no significant difference in digestibility between paddocks.The metabolizability of the herbage and the hay during the experiment was calculated to be 0.59 (±0.01) and 0.44 (±0.01), respectively.

The daily quantities of herbage, hay and total ME offered to the different groups are shown in Table Nº4.1.4.The quantity of total ME was increased significantly by the higher herbage allowance and by supplementation with hay ($P<0.0001$).

Table Nº4.1.3 Data for the in vivo digestibility of the hay,for the Dry Matter,Energy,and Organic Matter (%).

SHEEP Nº	DMD ----	ENERGY (%)	OMD ----
1	55.8	52.2	56.0
2	55.6	53.5	56.3
3	58.3	55.4	58.8
4	55.2	51.5	55.8
MEAN	56.2	53.2	56.7
± S.E.M.	0.01	0.01	0.01

Table Nº4.1.4.Mean values and results of ANOVA for the quantities of Metabolizable Energy offered from the Herbage,Hay and Total Energy Allowance (MJME/cow/day) for the four treatments.

	TREATMENTS					Sig.Level	
ME Allowance	L.A.	L.A.+	H.A.	H.A.+	$\pm SE_{LSM}$	DHA	HAY[1]
As Herbage	106	104	154	154	3.8	***	NS
As Hay	0.0	38	0.0	38			
Total	106	142	154	192	3.8	***	***

[1] See footnote for Table Nº4.1.1.

4.1.2 Herbage Intake.

The mean values for quantities of herbage, hay and apparent total DM consumed by the different groups are shown in Table Nº4.1.5. Herbage intake was increased significantly ($P<0.001$) by the higher herbage allowance and decreased significantly ($P<0.001$) by the supplementation with hay.The interaction between the effects of herbage allowance and hay supplementation was not significant ($P>0.05$).All the hay offered to the cows allocated to the supplemented groups was eaten.

The consumption of herbage was increased by 2.1 kgDM/cow/day by the higher pasture allowance, but was decreased by 1.7 KgDM/cow/day by supplementation of hay.

The mean values for quantities of fresh matter consumed and the DM concentration of the diet consumed by the different groups are shown in Table Nº4.1.5. Fresh matter consumed was increased significantly ($P<0.01$) by the higher herbage allowance but it was not significantly affected by supplementation with hay ($P>0.05$).The interaction between the effects of herbage allowance and hay supplementation was not significant ($P>0.05$). The groups with hay in their diet had higher DM concentration ($P<0.001$).

Total apparent DM intake was increased significantly ($P<0.001$) by the higher herbage allowance and by the supplementation with hay ($P<0.001$).The interaction between the effects of herbage allowance and hay supplementation was not significant ($P>0.05$).

The consumption of total apparent DM was increased by 2.1 kgDM/cow/day by the higher herbage allowance, and by 3.3 kgDM/cow/day by the hay supplementation.

Table Nº4.1.5. Mean values and results of ANOVA for the quantities of DM consumed from the Pasture, Hay, and Total apparent DM intake (KgDM/cow/day), Fresh Matter intake (kg/cow/day), and Concentration of the DM in the whole diet (grDM/kg eaten) for the four treatments.

	TREATMENTS					Sig.Level	
	L.A.	L.A.+	H.A.	H.A.+	$\pm SE_{LSM}$	DHA	HAY[1]
Apparent DM Intake :							
As Pasture	8.1	6.7	10.5	8.5	0.45	***	***
As Hay	0.0	5.0	0.0	5.0			
Total Intake	8.1	11.7	10.5	13.5	0.45	***	***
Fresh Matter	54.9	48.6	68.8	60.9	3.6	**	NS
Concentration of the DM	147	237	154	223	5.4	NS	***

[1] See footnote for Table Nº4.1.1.

The equations that best explain the variations in the herbage intake using two variables are:

$$\text{Total DMI} = 2.36 + 0.61\ \underset{(\pm 0.07)}{\text{DHA}} + 0.67\ \underset{(\pm 0.07)}{\text{HAY}}$$

$$(R^2 = 0.6815,\ P < 0.0001)$$

$$\text{Total DMI} = 10.54 + 0.87\ \underset{(\pm 0.10)}{\text{HAY}} - 0.003\ \underset{(\pm 0.0007)}{\text{RHM}}$$

$$(R^2 = 0.4870,\ P < 0.001)$$

DMI=Dry Matter Intake (kgDM/cow) daily.
DHA=Daily Herbage Allowance (kgDM/cow) daily.
HAY=Hay consumed (kgDM/cow) daily.
RHM=Residual Herbage Mass (kgDM/ha).

All the variables included in the model are significant($P<0.05$)

The calculated mean values for the quantities of the herbage, hay and total apparent total ME consumed daily by the different groups are shown in Table Nº4.1.6.

The ME intake as pasture was increased significantly ($P<0.001$) by the higher herbage allowance and was decreased significantly ($P<0.001$) by the supplementation with hay. The interaction between the effects of hay supplementation and herbage allowance was not significant ($P>0.05$).

The ME consumed as pasture was increased by 24 MJME/day by the higher herbage allowance, but was decreased by 20 MJME/day by supplementation with hay.

The total apparent ME consumed was increased significantly ($P<0.001$) by the higher herbage allowance and by the supplementation with hay ($P<0.01$). The interaction between the effects of hay supplementation and herbage allowance was

not significant (P>0.05).

The total ME consumed was increased by 18 MJME/day by the supplementation with hay, which represents only 47% of the ME consumed as hay.The total ME consumed was increased by 24 MJME/day by the higher herbage allowance, which represents 60% of the extra ME offered, compared with the lower allowance.

Table Nº 4.1.6.Mean values and results of ANOVA for the quantities of calculated ME consumed from the Pasture,Hay ,and Total apparent ME intake (MJME/cow/day) for the four treatments.

	TREATMENTS					Sig.Level	
ME Intake	L.A.	L.A.+	H.A.	H.A+	±SEM	DHA	HAY[1]
As Pasture	93	76	121	97	5.1	***	***
As Hay	0.0	38	0.0	38			
Total diet	93	114	121	135	5.2	***	**

[1] See footnote for Table Nº4.1.1.

4.1.3 Effect of Supplement on Intake of Pasture.

The mean values for the change in total intake of DM and of ME caused by the consumption of hay (1kg of DM or 1MJME) at the two herbage allowances in the six paddocks are shown in Table Nº4.1.7. Supplementation with hay resulted in an increase in total DM or ME consumed, although there was a decrease in the consumption of ME in paddock Nº3.

Table Nº4.1.7. Mean values and results of ANOVA for the changes in total intake of DM or ME caused by the consumption of hay (1kgDM or 1MJME) at the two herbage allowances in the six paddocks.

	Change in Total feed intake			
	kgDM per kg hayDM		MJME per MJME as hay	
Paddock Nº	LA+	HA+	LA+	HA+
1	0.80	1.07	0.70	1.11
2	0.95	0.56	0.93	0.35
3	0.33	-0.31	-0.15	-1.26
4	0.73	0.21	0.61	-0.15
5	0.86	0.91	0.81	0.88
6	0.59	0.68	0.37	0.50
Mean	0.72[a]	0.60[a]	0.56[a]	0.35[a]
± S.E.M.	0.10		0.16	

Means with the same letter are not significantly different ($P<0.05$) within dry matter or metabolizable energy.

4.1.4 Residual Herbage Mass.

Mean values and values for individual paddocks for residual herbage mass (RHM) are shown in Table Nº4.1.8. The quantity of RHM was significantly ($P<0.001$) increased by supplementation with hay and by the higher herbage allowance ($P<0.05$).The interaction between the effects of herbage allowance and hay supplementation was not significant ($P>0.05$).

The RHM was increased by 398 kgDM/ha by supplementation with hay, meanwhile the effect of the higher allowance was an increase of 204 kgDM/ha.

The mean values for the degree of defoliation are shown in Table Nº4.1.8. The degree of defoliation was decreased by the higher herbage allowance ($P<0.01$) and also by supplementation with hay ($P<0.001$). The interaction between the effects of herbage allowance and hay supplementation was not significant ($P>0.05$).

The degree of defoliation was decreased by 14% units by supplementation with hay and by 10% units by the higher herbage allowance.

Table Nº 4.1.8.Mean values and results of ANOVA for the quantities of Residual Herbage Mass of the paddocks (kgDM/ha),and Degree of Defoliation+(%) for the four treatments.

Residual Herbage Mass	TREATMENTS LA	LA+	HA	HA+	Sig.Level $\pm SE_{LSM}$	DHA	HAY[1]
Paddock Nº1	335	531	568	609			
Paddock Nº2	603	1022	923	1298			
Paddock Nº3	318	1514	490	1597			
Paddock Nº4	175	444	218	729			
Paddock Nº5	471	532	532	865			
Paddock Nº6	223	495	546	775			
MEAN	362	749	566	953	79	*	***
Degree-Defoliation	87	74	78	63	2.8	**	***

[1] See footnote for Table Nº4.1.1. + Calculated as 1-(RHM/Pregrazing Herbage Mass).

4.2 ANIMAL CHARACTERISTICS.

4.2.1 General.

The pre-experimental conditions of the animals are reported in the previous chapter (See Table Nº3.1.1.); the final liveweight and the body condition score of the animals were adjusted using the initial statistic as a covariate.

4.2.2 Liveweight Gain.

The mean values for the final liveweight adjusted for initial liveweight and the liveweight gain are shown in Table Nº4.2.1. The final liveweight of the cows was significantly ($P<0.01$)increased by the higher herbage allowance and by the supplementation with hay ($P=0.049$). The interaction between the effects of herbage allowance and hay supplementation was not significant ($P>0.05$).

Table Nº4.2.1.Mean values and results of ANOVA for the Final Liveweight (kg/cow) and Liveweight Gain and Net Liveweight Gain during 42 days of experimental period for the four treatments.

	TREATMENTS					Sig.Level		
	LA	LA+	HA	HA+	$\pm SE_{LSM}$	DHA	HAY	DHA*HAY
"Final	499	519	524	525	4.9	**	*	NS
Gain	9.8	28.4	33.7	35.3	4.9	**	NS	NS
'Net Gain	-13.1	7.8	14.2	13.6	4.7	**	*	*

NS:Not significant(P>0.05).The symbols (*), (**) and (***) indicate the significance levels of P<0.05,P<0.01 and P<0.001, respectively.
(")Adjusted,using initial weight as a covariate.
(')Calculated as Liveweight gain-weight of gravid uterus.

The liveweight gain during the 42 days of experimental period was increased significantly (P<0.01) by the higher herbage allowance, but the increase caused by supplementation with hay was not significant (P=0.052).The interaction between the effects of herbage allowance and hay supplementation was not significant (P>0.05).

The liveweight gain was increased by 15.4 kg by the higher herbage allowance.

Mean values for the net liveweight gain during the 42 days of experimental period are shown in Table Nº4.2.1. The net liveweight gain during the 42 days of experimental period

was affected by the interaction between herbage allowance and hay supplementation ($P<0.05$).

The net liveweight gain was increased when hay supplementation was offered at the low pasture allowance but decreased at the higher pasture allowance.The calculated mean liveweight gain of the gravid uterus of the the cows during the experiment was 21.2 ($\pm$2.7) kg.

Gains in liveweight and body condition score were measured for each individual cow, whereas apparent intakes of hay and herbage were measured for groups of cows. Bearing this limitation in mind, the two variables equation that best predicts the liveweight gain during 42 days was:

$$\text{L.W.G.(kg)} = -8.86 + 3.32\ \text{Hay} + 2.57\ \text{DHA}$$
$$(\pm 0.42) \quad (\pm 0.44)$$

($R^2=0.6080$, $P<0.0001$).

L.W.G.=Live weight gain during 42 days.
Hay=Amount of hay eaten (kgDM/day).
DHA=Herbage Allowance (Kg DM./cow/day).

All the variables included in the model are significant($P<0.05$).

The individual liveweight gains over the experimental period are reported in Appendix Nº 4.2.1

4.2.3 Body Condition.

The mean values for the final body condition score adjusted for initial body condition score and the change in body condition score during the 42 days of experimental period are shown in Table Nº4.2.2.

The final body condition score of the cows was significantly ($P<0.01$) increased by supplementation with hay and by the higher herbage allowance ($P<0.001$). The interaction between the effects of herbage allowance and hay supplementation was not significant ($P>0.05$).

The gain in body condition score during the 42 days of experimental period was increased significantly ($P<0.01$) by supplementation with hay and by the higher herbage allowance ($P<0.001$). The interaction between the effects of herbage allowance and hay supplementation was not significant ($P>0.05$).

The gain in body condition score during the experimental period was increased by 0.66 units by supplementation with hay, meanwhile the effect of the higher herbage allowance was an increase of 0.85 units.

Table Nº4.2.2.Mean values and results of ANOVA for the Final Body Condition Score (units) and Body Condition Score Gain during the 42 days of experimental period for the four treatments.

Body Condition	TREATMENTS LA	LA+	HA	HA+	$\pm SE_{LSM}$	Sig.Level DHA	HAY[1]
"Final	5.22	5.68	5.83	6.71	0.17	***	**
Change	0.05	0.53	0.71	1.56	0.18	***	**

[1] See footnote for Table Nº4.1.1.
(")Adjusted, using initial Body Condition as a covariate.

Gains in liveweight and body condition score were measured for each individual cow, whereas apparent intakes of hay and herbage were measured for groups of cows. Bearing this limitation in mind, the two variables equation that best predicts the gain in body condition score during 42 days was:

$$G.B.C.(Score) = -4.930 + 1.798\ Hay\ (\pm 0.17) + 0.059\ ME_{HA}\ (\pm 0.013)$$

$$(R^2 = 0.6901, P < 0.0001).$$

G.B.C.=Gain in score in body condition during 42 days.
Hay =Amount of hay offered (kgDM/day).
ME_{HA}=Allowance of metabolizable Energy from grass. (M.J.M.E./cow/day)

All the variables included in the model are significant($P < 0.05$)

The relationship between the liveweight gain and the body condition score gain is shown in the regression equation:

$$L.W.G. = 19.77 + 0.99\ G.B.C.$$
$$(\pm 4.07) \quad (\pm 0.41)$$

$(R^2 = 0.2100,\ P < 0.01)$. C.V.=51%

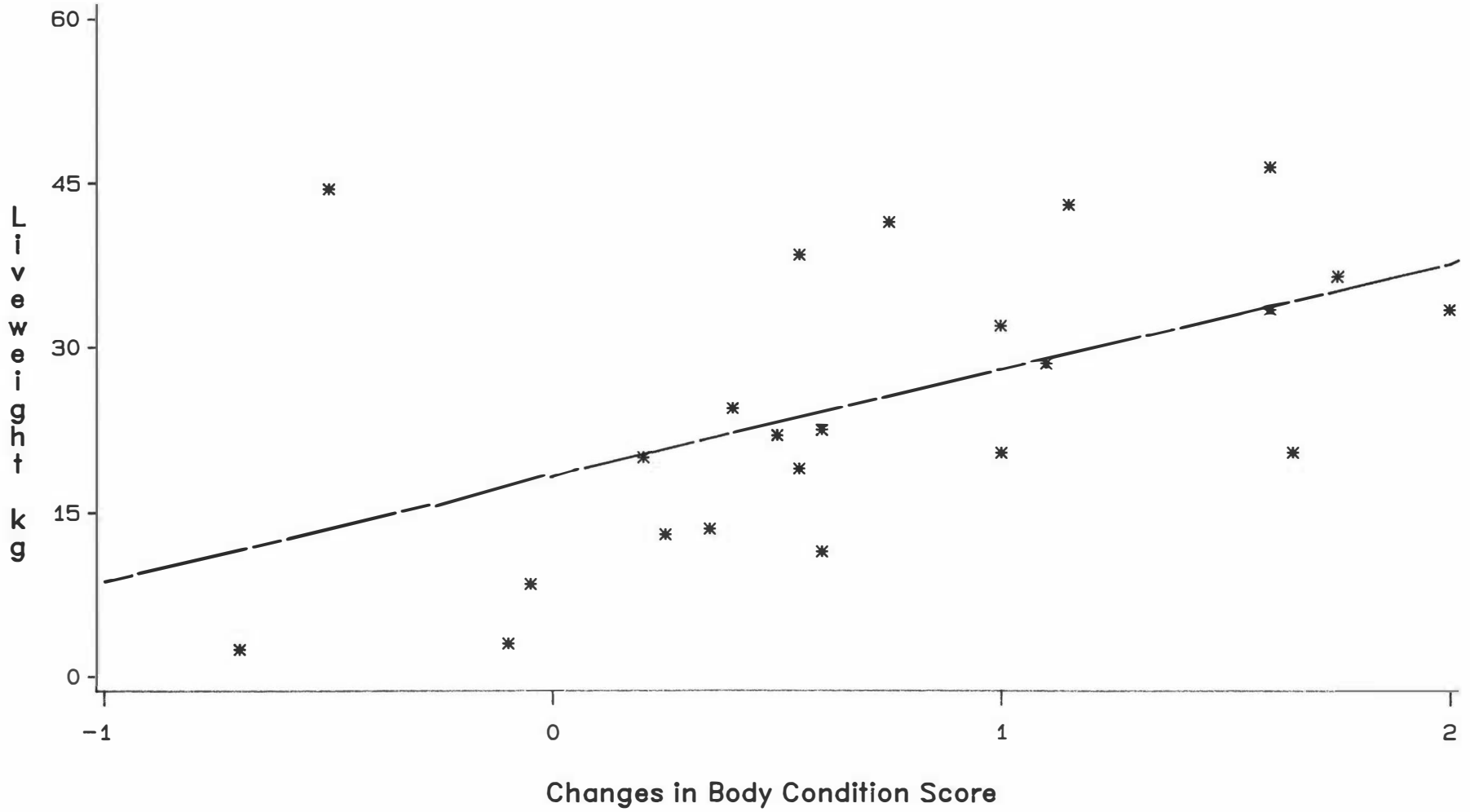
L.W.G=Liveweight gain during 42 days (kg)
G.B.C=Gain in score in body condition during 42 days (units).
C.V.=Coefficient of Variation.

The regression equation between the net liveweight gain and the body condition score gain is shown in Appendix Nº4.2.2.

The relationship between change in liveweight and body condition is shown in Figure Nº4.2.1.

The individual change in body condition score over the experimental period are reported in Appendix Nº 4.2.1.

Figure 4.2.1 Relationship between Liveweight Gains and Changes in Body Condition Score



Reference Line

4.2.4 Water Intake.

The mean values for the quantities of water drunk, ingested with pasture and the total quantities consumed (drunk+ingested with feed) are presented in Table Nº4.2.3. There were considerable variations between paddocks due possibly to climatic effects, so that quantities of water drunk have been shown for each paddock (Table Nº4.2.3.).

The quantity of water drunk was increased significantly ($P<0.001$) by the supplementation with hay, but was not significantly ($P>0.05$) affected by the herbage allowance. The interaction between the effects of hay supplementation and herbage allowance was significant ($P<0.05$).

The increase in quantity of water drunk was higher at the low herbage allowance (13.0 l) compared with the high herbage allowance (7.0 l).

The quantity of water ingested with pasture, which was inevitably associated with herbage intake, was increased significantly ($P<0.01$) by the higher herbage allowance and decreased significantly ($P<0.01$) by the supplementation with hay. The interaction between the effects of herbage allowance and hay supplementation was not significant ($P>0.05$).

The quantity of total apparent water consumed was increased significantly ($P<0.05$) by the higher herbage allowance, but it was not significantly affected by supplementation with hay. The interaction between the effects of herbage allowance and hay supplementation was not significant ($P>0.05$).

The total apparent water consumed was increased by 13.0 l by the higher herbage allowance.

Table Nº4.2.3. Mean values for the quantities of Water Drunk (litres/cow/day) in each paddock and mean values and results of ANOVA for the Water Drunk, Water ingested with the Pasture and with the Hay, and Total Apparent Water consumed (water drunk and ingested with feed) for the four treatments.

	TREATMENTS					Sig.Level[1]		
	LA	LA+	HA	HA+	$\pm SE_{LSM}$	DHA	HAY	DHA*HAY
Paddock Nº1	10.6	23.3	14.0	24.8				
Paddock Nº2	13.4	26.4	20.3	26.2				
Paddock Nº3	9.4	24.1	11.6	19.8				
Paddock Nº4	9.7	20.2	10.6	15.0				
Paddock Nº5	13.9	25.8	16.1	23.8				
Paddock Nº6	16.9	30.8	19.8	22.9				
Water Drunk	12.2	25.2	15.3	22.3	1.4	NS	***	*
Water ingested with Pasture	56.4	43.2	69.8	56.6	5.1	**	**	NS
Water ingested with Hay	0.00	0.85	0.00	0.85				
Total Apparent Water Consumed	68.6	69.4	85.1	79.1	4.7	*	NS	NS

[1] See footnote for Table Nº4.2.1.

Mean values for the relationships between DM intake and water drunk, hay DM intake and extra water drunk, DM intake and apparent total water consumed are shown in Table Nº4.2.4.

The quantity of water drunk per kg total DM consumed was significantly increased by supplementation with hay ($P<0.05$). However, the total water consumed per kg total DM consumed was decreased by hay supplementation ($P<0.001$).The effect of herbage allowance was not significant ($P>0.05$).The interaction between the effects of herbage allowance and hay supplementation was not significant ($P>0.05$).

The apparent total water consumed was decreased by 2.3 l/kg DM consumed by supplementation with hay.

The increase in water drunk, due to hay supplementation was 3.0 and 1.9 l extra water per kg hay DM consumed at the low and hay herbage allowance respectively.

Table Nº4.2.4. Mean values and results of ANOVA for various measures of Water Consumption in relation to DM Intake. Water Drunk and Total DM intake (litres/kgDM), Extra Water Drunk and Hay DM Intake (litres/kg hay DM) and Total Apparent Water Consumed and Total DM intake (litres/kgDM) for the four treatments.

	TREATMENTS					Sig.Level[1]		
	LA	LA+	HA	HA+	$\pm SE_{LSM}$	DHA	HAY	DHA*HAY
Water Drunk per DM Intake	1.6	2.2	1.5	1.7	0.18	NS	*	NS
Extra Water Drunk per Hay DM Intake	0.0	3.0[a]	0.0	1.9[b]				
Total Apparent Water Consumed per DM Intake	8.5	6.0	8.0	5.9	0.16	NS	***	NS

The same letters are not significantly different (P>0.05).

[1] See footnote for Table Nº4.2.1.

The mean values and ranges of the enviromental conditions during the experiment are shown in Table Nº4.2.5.

Table Nº4.2.5.Mean values and range of the Enviromental Conditions during the experimental period.

	MEAN	SE_m	RANGE
Sunshine (hours/day)	3.77	± 0.23	(0.0 - 9.0)
Rainfall (mm./day)	2.67	± 1.52	(0.0 - 32.1)
Evaporation(mm./day)	0.75	± 0.09	(0.0 - 2.8)
Relative humidity	89.43	± 0.55	(71.0 - 98.0)
Wind (day tot.Km.)	172.0	± 7.19	(51 - 382)
Temperature °C			
Minimum	3.42	± 0.27	(-2.0 - 10.3)
Maximum	12.38	± 0.18	(8.3 - 17.4)
Average	7.90	± 0.19	(3.9 - 12.5)

Grassland Division D.S.I.R.Palmerston North
(Lat.40°23'S.;Long.175°37'E.)

The relationships between the environmental conditions and water drunk are shown in Table Nº4.2.6. The highest positive correlation with water drunk was hours of sunshine ($P<0.01$), whereas minimun temperature, wind and rainfall were negatively correlated with the amount of water drunk.The amount of rainfall (mm./day), sunshine hours and minimun temperature during the experiment had the major influence on water intake of the 7 enviromental factors.

Table 4.2.6. Correlation Coefficients between environmental conditions and quantities of Water Drunk during the experimental period.

Climatic Effect	Correlation Coeficients	Level Significance[1]
Rainfall	-0.247	**
Relative Humidity	-0.180	*
Sunshine Hours	0.444	***
Average Temperature	-0.148	NS
Maximun Temperature	0.124	NS
Minimun Temperature	-0.294	***
Wind Speed	-0.202	*

Pearson Correlation Coefficients.

[1]See footnote for Table Nº4.1.1.

The regression equation that best explains the variations in the water drunk per day using two variables, considering enviromental factors and characteristics of the diet is:

$$W.D.D. = 11.04 - 0.80\ Rain + 0.03\ CDM$$
$$(\pm 0.14) \quad (\pm 0.003)$$

$$(R^2 = 0.8642,\ P < 0.0001)$$

W.D.D.=Water Drunk Daily (litres).
Rain =Rainfall (mm./day)
CDM. =Concentration of DM(gr)per fresh kg eaten.

All the variables included in the model are significant($P<0.05$).

4.2.5 Animal Behaviour.

The rate of biting (RB) was measured on twelve days during the experiment, for the first three hours on the fresh pasture given each day (methods described in materials and methods), and mean values recorded are shown in Table Nº4.2.7.When a cow was eating hay, the data was not included in measurement of RB.

The RB during the first hour was significantly ($P<0.001$) increased by the supplementation with hay and by the higher herbage allowance ($P<0.01$).The interaction between the effects of herbage allowance and hay supplementation was not significant ($P>0.05$).

The rate of biting was increased by 2.6 bites/minute by the higher pasture allowance and by 5.1 bite/minute by the supplementation with hay.

The RB during the second hour was significantly ($P<0.001$) increased by the higher herbage allowance and by the hay supplementation ($P<0.05$).The interaction between the effects of herbage allowance and hay supplementation was not significant ($P>0.05$).

During the second and third hours, RB decreased for the four treatments.After the third hour the number of cows grazing in the groups supplemented with hay declined rapidly.

Table Nº4.2.7. Mean values and results of ANOVA for the Rate of Biting during the First, Second and Third Hour (bites/minute/cow) after the cows were allocated to fresh pasture for the four treatments.

	TREATMENTS					Sig.Level	
Rate of Biting	LA	LA+	HA	HA+	$\pm SE_{LSM}$	DHA	HAY[1]
a)1st. Hour	50.9	55.4	52.9	58.6	0.96	**	***
b)2nd. Hour	45.0	50.6	52.2	54.1	1.46	***	*
c)3rd. Hour	39.5	44.9	46.9	47.0	1.90	*	NS

[1] See footnote for Table Nº4.1.1.

The intake per bite was estimated indirectly, using a rising plate meter (See Materials and Methods) to estimate the change in herbage mass which occured during the first two hours after the areas of fresh pasture were offered each day. The mean values of the calculated intakes per bite and estimated intake after the first hour are shown in Table Nº4.2.8.

Total apparent herbage intake during the first hour was similar (approx.5 kgDM) for all the four treatments, whereas intake per bite was significantly ($P<0.05$) decreased by supplementation with hay at both allowances.

Table Nº4.2.8. Mean values and results of the ANOVA for the Intake per Bite (gr/bite) and Apparent Total DM Intake (kgDM) during the first hour after the areas of fresh pasture were offered each day for the four treatments.

	TREATMENTS					Sig.Level	
	LA	LA+	HA	HA+	$\pm SE_{LSM}$	DHA	HAY[1]
Total Intake	5.1	4.8	4.8	5.2	0.36	NS	NS
Intake per Bite	1.72	1.35	1.48	1.38	0.11	NS	*

[1] See footnote for Table Nº4.1.1.

The total apparent herbage DM consumed per cow in the first hour of feeding, was equivalent to aproximately 62% and 71% of the total daily herbage intake by cows on the low allowance with or without hay supplementation respectively.

The data for intake per bite and total DM intake for the second hour were affected by the limitations of the methodology used because of pugging after the first hour especially in the low herbage allowance groups.Those limitations resulted in insufficient observations for those groups.

Mean values for the total periods of time spent in the various types of behaviour during the hours of daylight, are shown in Table Nº4.2.9.

Table Nº4.2.9. Mean values and results of ANOVA for the Total Periods of Time Spent in the various Types of Behaviour during the hours of Daylight (minutes) for the four treatments.

	TREATMENTS					Sig.Level[1]		
Event Observed	LA	LA+	HA	HA+	$\pm SE_{LSM}$	DHA	HAY	DHA*HAY
Grazing	391	225	388	282	17.2	NS	***	NS
Eating Hay	0	121[a]	0	117[a]				
Ruminating	8	66	6	63	6.1	NS	***	NS
Drinking Water	2	2	2	1	0.8	NS	NS	NS
Resting	156	143	162	95	11.6	NS	**	*

[1] See footnote for Table Nº4.2.1.
Mean values with the same letters are not significantly different (P>0.05).

The time that the cows spent grazing was significantly (P<0.001) decreased by supplementation with hay. The cows that consumed hay spent more time ruminating (P<0.001) compared with the unsupplemented cows. The interaction between the effects of herbage allowance and hay supplementation was not significant (P>0.05).

The time that a cow spent grazing was decreased by 136 minutes during daytime by the supplementation with hay, but the time the cows spent ruminating was increased by 57 minutes

during daytime. Between the high and low herbage allowance groups the time spent grazing and ruminating was similar, although the amount eaten was different.

All the groups of cows spent similar time drinking water. The time spent eating hay by the supplemented groups were similar at the low or high herbage allowance.

The time spent resting during the daytime was affected by the interaction between the effects of herbage allowance and hay supplementation ($P<0.05$). The time observed resting was higher for the unsupplemented cows at the high herbage allowance, but was lower for the supplemented cows at the low herbage allowance. Inevitably, all the events are mutually exclusive (See Materials and Methods).

CHAPTER 5

5 DISCUSSION

5.1 THE FEEDS AND FEEDING LEVELS.

5.1.1 Pregrazing Herbage Mass.

The significant difference observed in pregrazing herbage mass (Table Nº 4.1.2.) was not planned but ocurred by chance due to the heterogeneity within the paddocks, as the animals were randomly allocated to the different areas at the beginning of each paddock. The average herbage mass offered in the present experiment was slightly lower than the range of values within which it was suggested that DM intake was unaffected by herbage mass (Meijs,1981; Holmes,1987). However, it is very unlikely that DM intake was affected by the 195 kgDM/ha difference in herbage mass in the present experiment. The pregrazing masses were cut by the same person during the whole experiment to try to avoid changes in determination as was suggested by T'Mannetje (1978) and Thomson (1986).

The DM concentration of the pasture in the different paddocks was similar to the values reported by Holmes and Wilson,(1984) during the winter, but was on average 3 units lower than the value of 18%, below which the dry matter of lactating cows may be limited (Verite and Journet,1970).The present low value was probably related to the wet conditions during the experiment.

5.1.2 Herbage and Total DM Allowance.

The herbage allowance offered to the cows was on average 19 and 27 grDM/kgLW for the low and high level respectively. This is similar to the low (19 grDM/kgLW) and moderate (28 grDM/kgLW) herbage allowance utilized by Holmes and McClenaghan (1980) and the very low (17 grDM/kgLW) and low (27 grDM/kgLW) herbage allowance reported by Nottingham (1978) but lower than the levels offered by Hodgson and Jamieson (1981) for dry cows (Figure Nº 5.2.2.).

Total DM allowance for the LA+ and HA were 29 grDM/kgLW and 27 grDM/kgLW respectively, while the HA+ had a total DM allowance on average of 38 grDM/kgLW, below the moderate DM (45 grDM/kgLW) allowance offered as herbage by Nottingham (1978).

5.1.3 Digestibilities of Feeds.

The in vivo OM digestibility of the hay (55%)(Table Nº 4.1.3.) could be considered to be of medium quality (Jagush,1984). The difference between the in vivo and in vitro DM digestibilities of the hay was lower than the 2.5% suggested as the residual standard deviation for the in vivo prediction with in vitro digestibilities (Roughan and Holland,1977; LeDu and Penning,1982).

In the calculations of the quantities of ME offered and consumed it was assumed that the digestibilities were not affected by the types of feed eaten, based on the suggestion of Aerts et al (1986) which indicated that associative digestibility effects between feeds in a ration are neglible for most rations. It was also assumed that the level of supplementation did not affect the pasture selectivity by the animals, based on the findings of Eldridge and Kat (1980) on

grazing cows supplemented with hay, which found that hay feeding did not affect digestibilities of the herbage selected by the animals.

The *in vitro* OM digestibility of the pasture was 82%(±0.4), on average 1.9 units higher than the values reported by Bryant and Trigg (1982) during the same season.

The proportion of DM offered as hay to the low and high allowance was 36% and 27% of the total allowance respectively. However, the proportion increased to 44% and 37% of the total DM consumed, for the low and high allowance respectively, because the cows consumed all the hay offered, but not all of the herbage offered. Assuming that the DM digestibilities of the hay and pasture were not additive (Eldridge and Kat,1980), the calculated mean DM digestibilities of the supplemented groups were 65.0% and 66.0% for the low and high allowance respectively, and 73.0% for the unsupplemented animals.

5.1.4 Herbage and Total ME Allowance.

The ME allowance as pasture at the low and high allowance respectively was 1.5 and 2.2 times the initial maintenance requirements suggested by Holmes and Grainger (1982) for cows fed pasture indoors. The total ME allowance was 1.5, 2.0, 2.2 and 2.7 times those maintenance requirements for the LA,LA+,HA, and HA+ respectively.

5.2 EFFECT OF HERBAGE ALLOWANCE.

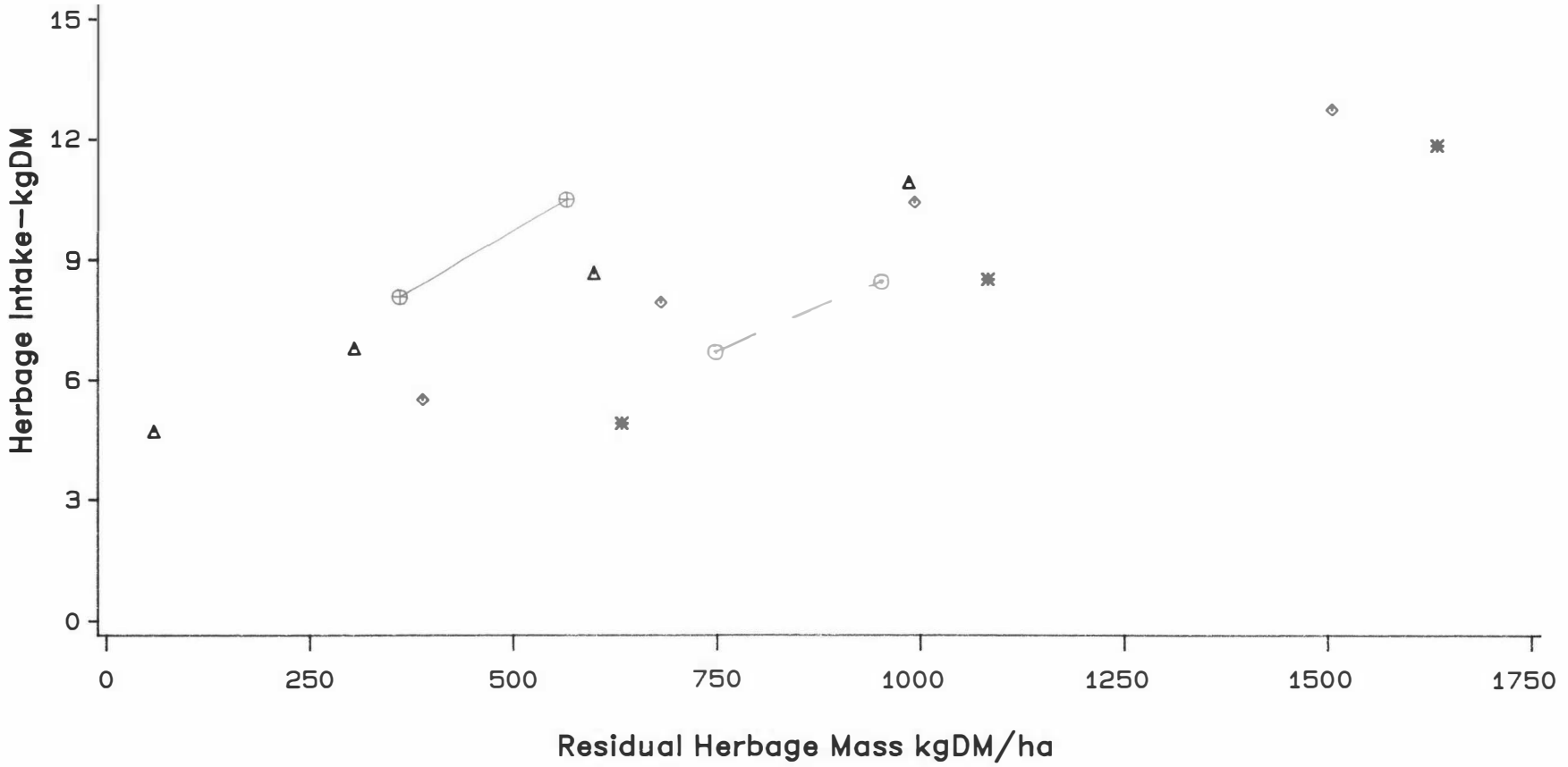
The main effects of herbage allowance and supplementation with hay were usually significant. The interaction between herbage allowance and supplementation with hay was not significant. Therefore, the results are discussed under main treatments for convenience of the reader.

5.2.1 Residual Herbage Mass.

The quantity of residual herbage mass was increased by the higher herbage allowance (Figure Nº 5.2.1). There was an increase of 204 kgDM/ha in postgrazing mass in the high herbage allowance groups compared with the low allowance groups. The postgrazing herbage mass was increased significantly by the higher herbage allowance as reported by Combellas and Hodgson (1979), Bryant (1980), Glassey et al (1980), Holmes and McClenaghan (1980), Mitchell (1985) and Hoogendoorn (1987). The effect of the level of herbage allowance was similar to the values reported by Holmes and McClenaghan (1980) for dry cows between 6 and 9 kgDM/cow/daily allowances, but lower than the difference of 300 kgDM/ha observed between similar allowances (13 vs 9 kgDM/cow/day), or the 310 kgDM/ha difference reported by Nottingham (1978) between 14.3 kgDM/cow/day and 9.7 kgDM/cow/day allowance (Figure Nº 5.2.1).

It is important to note that the residual mass could be affected by the pregrazing herbage mass due to the relationship between residual herbage mass and pregrazing mass (Combellas and Hodgson,1979;Holmes,1987).This relationship could influence sward density and displace the limiting horizon of grazing of the low pregrazing mass groups. In the present study, the effect of offering an additional kgDM of pasture per ha increased the residual herbage mass on average by 0.25 kgDM/ha.

Figure 5.2.1 Relationship between Residual Herbage Mass and Pasture Intake (kgDM/cow/day)



* Holmes and McClenaghan, 1980

The residual herbage mass of the unsupplemented cows offered the low allowance or the high allowance were lower than the values reported by Nottingham (1978), Holmes and McClenaghan (1980), Ngarmsak (1982) for similar herbage allowances and pregrazing mass during the winter time (Figure Nº 5.2.1). This might be associated with the wet conditions and the heavier animals utilized in this experiment that complicated the postgrazing cutting technique (Walter and Evans,1979).

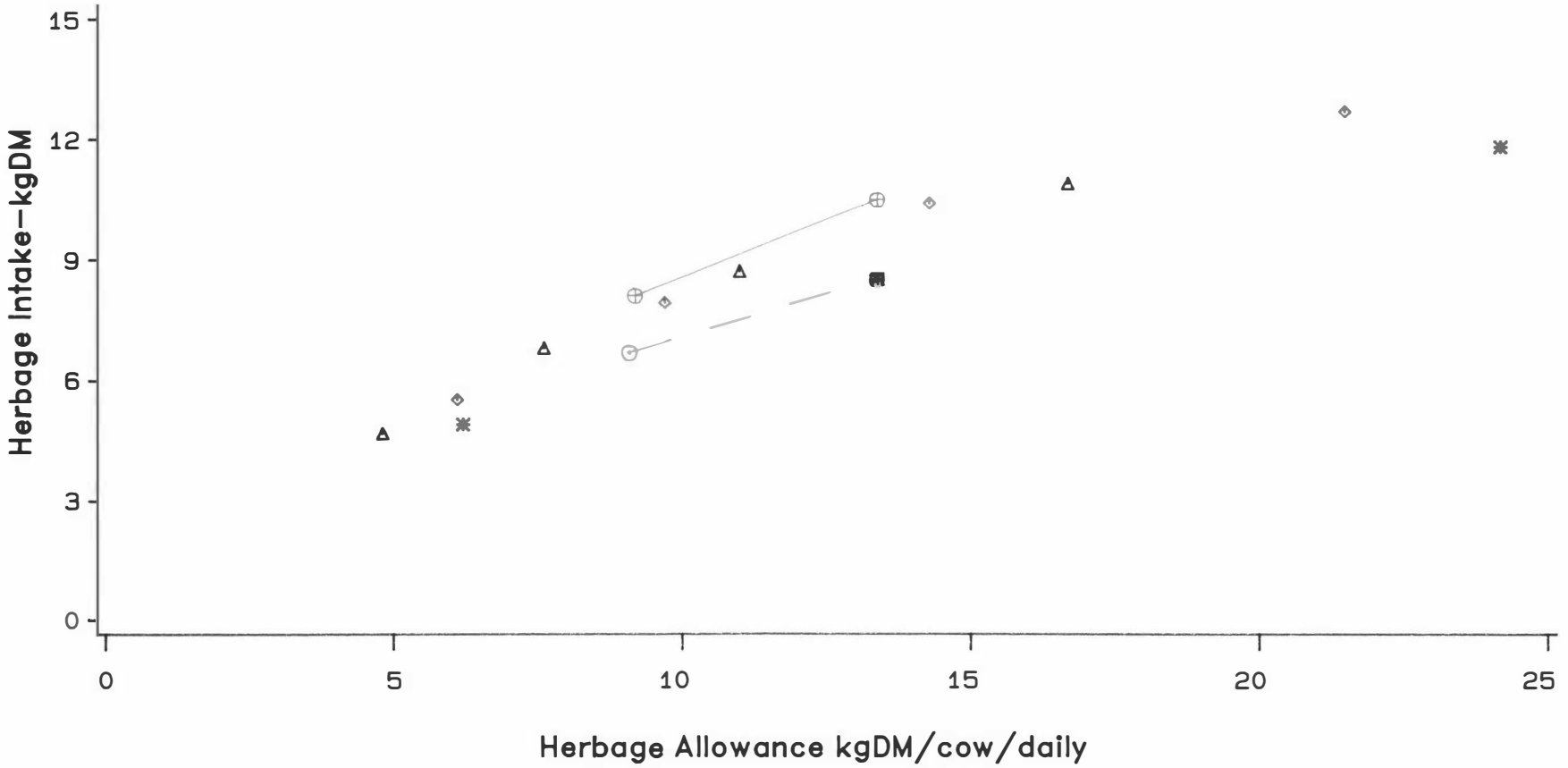
5.2.2 Herbage Intake.

Herbage intake was increased by the higher herbage allowance (Table Nº 4.1.5.). The consumption of herbage was increased by 2.1 kgDM/cow/day by the higher pasture allowance. The increase in herbage intake was 0.5 kgDM per additional kgDM offered as herbage allowance.

The increase in herbage intake observed with the higher herbage allowance was similar to the response reported by other authors (Nottingham,1978; Holmes and McClenaghan,1980; Ngarmsak,1982; Jamieson and Hodgson,1981) for non-lactating cows (Figure Nº 5.2.2.), and for lactating cows in early lactation (LeDu et al,1979; Glassey et al,1980; Bryant,1980; Meijs,1981; Grainger et al,1982; King and Stockdale,1984; Hoogendoorn,1987) or in late lactation (Stockdale and King,1982; Bryant,1980), or sheep (Geenty and Sykes,1986).

Some authors have suggested that herbage allowance has a direct effect on herbage intake (Hodgson,1976; Bryant,1980). However, Hodgson (1984) suggested that the effect is indirect, through the influence of herbage allowance on rate of change in sward conditions during grazing. At the low herbage allowance

Figure 5.2.2 Relationship between Herbage Allowance and Pasture Intake (kgDM/cow/day)



* Holmes and McClenaghan, 1980

the possible mechanism of control of intake was probably related to the inaccessibility of residual herbage (Hodgson,1977; Leaver,1986).

The herbage intake of the animals was also calculated using the method described by Baker (1982) based on animal performance(APT). The requirements for maintenance were those suggested by Holmes and Grainger (1982) and the requirements for pregnancy and change in liveweight were estimated from ARC (1980). Bearing in mind the inaccuracies associated with this technique (Baker,1982; Phillips and Leaver,1985a), the herbage intakes calculated showed the same trend as that shown by the values determined by the cutting before and after grazing(BAT), but all the absolute values were lower. The quantities of pasture consumed calculated indirectly by Baker's technique were 5.9 kgDM, 4.5 kgDM, 8.2 kgDM and 5.4 kgDM for the LA, LA+, HA and HA+ respectively.

It is important to observe that the values of estimated herbage intake calculated by the APT technique without supplements were closely related to the values reported by Nottingham (1978); Holmes and McClenaghan (1980) and Ngarmsak (1982), using cutting techniques during drier winters.

The estimated values of herbage intake by the before-after cutting were higher than the feed required calculated using the data in ARC (1980) or MAFF (1984).

It is likely that herbage intake was in fact overestimated due to wet conditions, reducing the accuracy of the ground-level cutting technique on those areas that have been trampled or are rough (Walters and Evans,1979, Meijs,1981). However, it is also likely that the ME_m for grazing animals is underestimated by ARC (1980) or MAFF (1984) (See Section Nº 5.6.5).

5.2.3 Total DM Intake.

Total apparent DM intake was increased by the higher herbage allowance (Table Nº 4.1.5.).

The DM intake of the animals was 1.6, 2.3, 2.1 and 2.7% liveweight for the LA,LA+,HA and HA+ respectively.

5.2.4 Total ME Intake.

The metabolizable energy concentration of the feeds was calculated using the D-value (See Materials and Methods). However, the ME was also calculated using the equation ME(MJME/kg DM) = 0.181±0.01 OMD -2.68 (±0.06). proposed by Bryant and Trigg (1982) and the equation ME(MJME/kgDM) = 0.15 DOMD + 0.007 PROT - 0.74 proposed by Osburn (1980), as is shown in Table Nº 5.2.1.

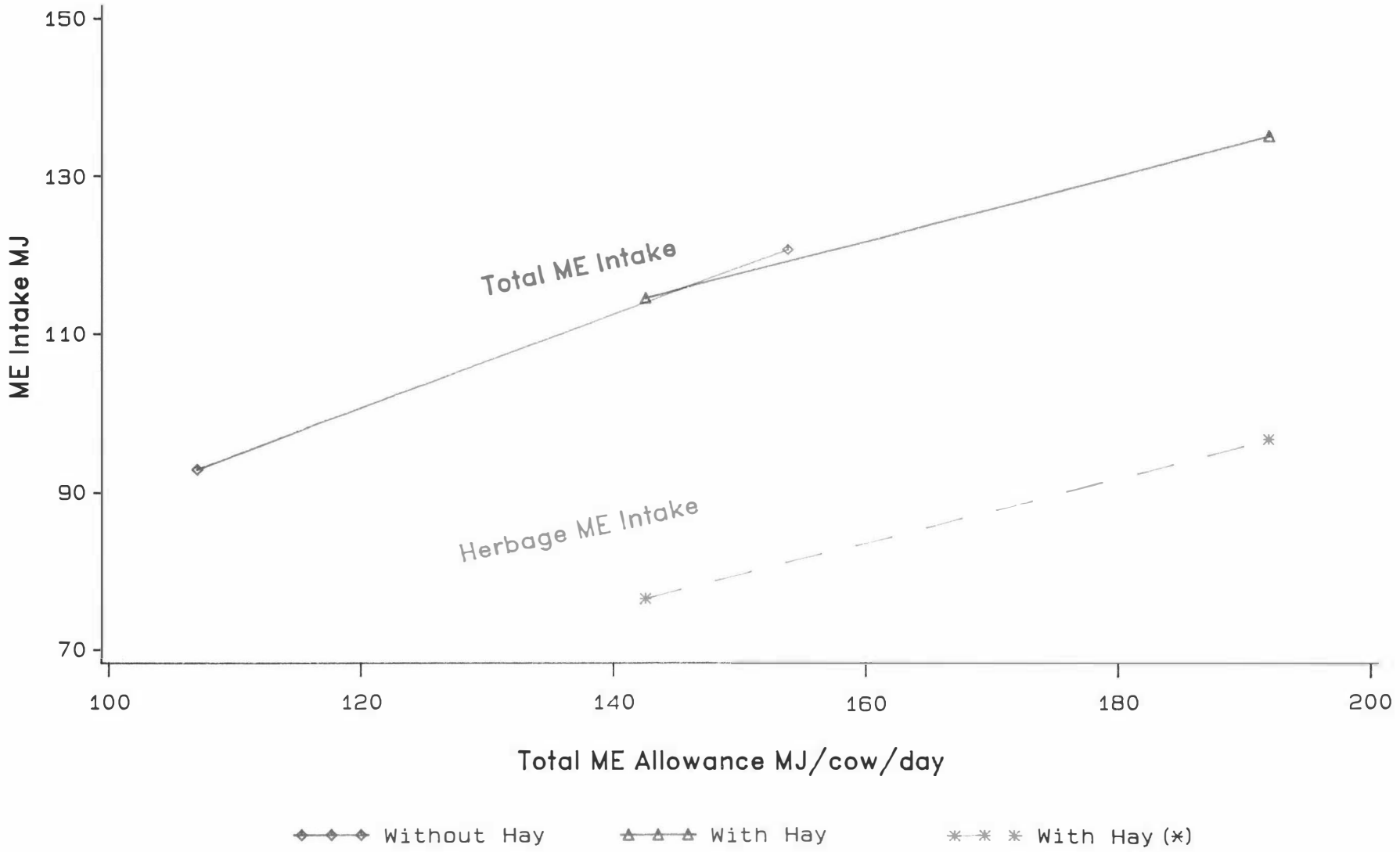
Table Nº 5.2.1 Comparison of the calculated total ME consumed using three different methods of calculation.

	LA	LA+	HA	HA+	SE_{LSM}	ALLHAY
Present Experiment	93	114	121	135	5.3	*** **
-1-	98	120	127	143	5.3	*** **
-2-	98	121	127	143	5.3	*** **

-1- Bryant and Trigg,1982.

-2- Osburn,1980.

Figure 5.2.3 Relationship between ME Allowance and ME Intake



The values for ME intake calculated by the use of Osburn (1980) and Bryant and Trigg (1982) were approximately 5% higher than those calculated in the present study.

There is not much information for predicting ME for grazing cows supplemented with feeds of lower quality than the pasture.The use of the D-value can be a useful aid for mixed diets.

ME intake as pasture was increased by the higher herbage allowance (Figure Nº 5.2.3). For each additional kg of pasture allowance offered the intake of energy from pasture was increased by 5.7 MJME. This was similar to the values calculated from Holmes and McClenaghan (1980).

5.3 EFFECTS OF HAY SUPPLEMENTATION.

5.3.1 Residual Herbage Mass.

Hay supplementation increased the postgrazing herbage mass by 398 kgDM/ha compared with the unsupplemented groups (Table Nº 5.3.1). This effect of supplementation on the quantity of herbage after grazing had been observed by several authors as is shown in Table Nº 5.3.1, for different types of diets and for lactating cows. There appears to be no data for non-lactating cows at lower levels of feeding.

At a low herbage allowance (7.7 kgDM/cow/day), Grainger (unpublished) reported no substitution of pasture DM intake by concentrate and consequently supplemented cows had similar residual masses to the unsupplemented cows. A comparable finding was reported by Stockdale and Trigg (1985) for the low herbage allowance (15 kgDM/cow/day), with 1.8 or 3.6 kgDM

concentrates.

Table Nº 5.3.1. Effect of Supplementation on Residual Herbage Mass (KgDM/ha).

Reference and Brief Experimental Details	DHA kgDM cow/day	Supplement Consumed daily kgDM/cow	kgDM/ha	Change RHM due to Supplement kgDM/ha
Present Study	9.2	5.0	1555	+387
Non-lactating Cows;Hay	13.4	5.0	955	+387
Bryant,1978	20.0	8.8	1311	+560
Midlactation;Silage	20.0	7.8	1162	+490
Stockdale et al,1981	27.1	5.0	795	+470
Early Lactation; Hay	21.6	7.0	1423	+310
Bryant and Trigg,1982	15.0	2.1	-	+170
Early Lactation;Silage	15.0	4.0	-	+390
Stockdale and Trigg,	16.0	1.8	563	+ 50
1985	14.9	3.6	1199	-110
Late Lactation;	15.2	6.3	1969	+460
Concentrates	25.8	1.8	347	+320
	26.6	3.5	676	+320
	26.3	6.2	1197	+330
Grainger,unpublished	7.7	3.2	1010	+ 9
Early lactation;	17.1	3.2	438	+124
Concentrates	33.0	3.2	235	+111

These results were different in the present study, probably because the low allowance was not as restrictive for dry cows as those utilized for lactating cows, in the experiments to which reference has been made.

Supplementation reduced the degree of defoliation by 14%, following the trend reported by Bryant (1978), Stockdale et al (1981), Bryant and Trigg (1982), Stockdale and Trigg (1985) and Phillips and Leaver (1985a;1985b), although this effect was influenced by the level of feeding, type of supplement and type of animal, reflecting the level of substitution of pasture DM by the supplement (Section Nº 5.4.)

The supplementation of hay allowed an increased carrying capacity for the farm during the winter, but the effect was not complete replacement, as it is assumed in the feed planning (Frengley,1973; Monteath,1973; Milligan et al,1987), due to the different ME of the two feeds and the substitution effect. However, the LA+ had a higher DM intake than the HA at similar DM allowances, but the calculated ME intake was lower for the LA+ than the HA showing that the replacement was not complete, as is assumed when the comparison is done considering the DM intake.

Therefore the increase in stocking rate is not proportionate to the level of supplementation, although the increase in post grazing mass could increase the amount of pasture growth during the winter (Brougham,1970; Hoogendoorn,1987) due to a higher LAI. Although the RHM observed in the present study was lower than the 2200 kgDM/ha reported by Gray and Matthews (1982) as the critical RHM to achieve maximum winter growth. Unfortunately, it was not possible to determine the influence of supplementation with hay on pasture growth, pasture quality in the spring or changes in botanical composition nor consequently the influence on the stocking rate.

5.3.2 Herbage Intake.

The consumption of herbage was decreased by 1.7 kgDM/cow/day by supplementation of hay (5 kgDM/cow/day) (Figure Nº 5.2.2).

The decrease in herbage intake observed in cows supplemented by hay has been reported with lactating cows by several authors (Bryant,1978; Stockdale et al,1981; Bryant,1982; Bryant and Trigg,1982; Stockdale and King,1982; Jennings and Holmes,1984; Meijs and Hoekstra,1984; Phillips and Leaver,1985a;1985b; Arriaga-Jordan and Holmes,1986b; Skatelum,1986; Grainger,1987). However, there appear to be no data for non-lactating cows on lower levels of feeding.

Stockdale and Trigg (1985) and Grainger (1987) feeding concentrates to lactating cows pointed out that at very low levels of herbage allowance the supplement did not influence herbage intake but acted as a complement of the diet.

The quality of the supplement can affect the herbage intake of cows supplemented with concentrates (Jennings and Holmes,1984;Meijs,1986) due to changes in the rumen fermentation.

The interaction between herbage allowance and supplementation was not significant. This agrees with the results of Joblin (1968) in beef cattle supplemented with hay or grass silage, and of Phillips and Leaver (1985a) between stocking rate and hay supplementation on herbage intake for continuously stocked lactating cows and is contrary to the reports by Meijs and Hoekstra (1984); Stockdale and Trigg (1985); Stakelum (1986) and Grainger (1987) who offered concentrates to lactating cows (Table Nº 5.4.1.), probably related to the difference between the intake of nutrients from herbage and the nutrient requirement (Meijs,1981). The

possible reasons were that the levels of allowance offered in the present trial were not very contrasting and also the quality of the supplement (Bines,1979) could play a role in the different mechanisms controlling herbage intake.

Possible Reasons for Selection of the Hay Supplemented cows chose to consume all of their hay, despite the fact that, as judged from the residual herbage mass at the lower allowance, herbage was still accessible to be grazed, and even though the hay was of lower quality than the pasture. A similar situation was observed at the high herbage allowance. The question to ask is why?

In wild animals, there is a strong tendency to maximize the ingestion of energy and other essential nutrients per unit time spent in feeding. The control imposed on domestic animals may not allow this degree of choice though there is selection between types of food (Arnold,1987).

The selection by the cows of the food of lower quality, thereby limiting its potential level of feeding, was probably related to the ease of ingestion (Leaver,1986) particularly at the low allowance, the desire for a quick meal (Birrell,1984; Phillips and Leaver,1986) or the desire for a varied diet (Leaver et al,1968). Another possible reason is the presence of a limited quantity of a feed (hay), stimulates competitive feeding behaviour in a group of cows in relation to the limited feed, leading to an apparent preference for that feed relative to the other less limited feed pasture. Probably the time and frequency of the hay offered can affect the 'preference' of the hay over the pasture.

Possible Reasons for the Reduction in Herbage Intake The reasons for the reduction in the herbage intake when hay was offered (Table Nº 4.1.5.) are not completely clear. It could be associated with the lower quality of the hay offered compared with the pasture that reduced the overall quality of

the diet consumed. This effect could develop a lower rate of passage (Bines,1971) with an increase in the rate of digestion (chemical and biological) because of the higher 'ingestibility' of the diet, changing the pattern of behaviour by increasing the time of rumination and the bulk in the rumen (Alderman,1983).

The reduction in pasture intake caused by supplementation at the high allowance can probably be explained partially by the physical limitation, considering that the possible increase in cell wall content (Van Soest,1982) due to the summer harvested hay or higher dietary density (volume per unit weight of "indigestible" material)(Baumgardt,1970) could displace pasture in proportion to the space occupied by the two diets. However, the levels of energy consumed could also have affected the response.

At the low allowance group the explanation is not clear, however, it is not expected that just one mechanism of control was involved.

The relative importance of the behavioural mechanisms of control of intake are not completely clear. Total grazing time was reduced in the cows supplemented with hay (27 minutes in daylight/kg hay DM) which is similar to reports by Phillips and Leaver (1985a;1985b) for lactating cows. It is interesting to note that the cows in the low allowance group appeared to consume almost all their herbage in the first 2 hours of grazing, indicating that the remaining hours of grazing were essentially fruitless.

5.3.3 Total DM Intake.

Despite the substitution effect, hay supplementation increased total DM intake at both levels of pasture allowance (Table Nº 4.1.5.). This effect of supplements has been reported by many authors not only for non-lactating cows (Eldridge and Kat,1980; Saker and Holmes,1974), but also for lactating cows (Stockdale et al,1981; Stockdale and King,1982; Bryant,1983b; Phillips and Leaver,1985a;1985b Stockdale and Trigg,1985; Grainger,1987). However, this relationship has not been found at high levels of pasture allowance with concentrates (Leaver et al,1968; Bines,1979).

When pasture DM intake was estimated by the animal performance method, the increase in total DM were 0.72 and 0.44 kgDM per kg hay DM eaten, at the lower and higher allowance respectively. The corresponding values for DM intake calculated from herbage masses before and after grazing were 0.72 and 0.60 kg total DM/kg hay DM.

The increase in total DM when supplements were offered was reported by all the experiments reviewed (Table Nº 5.4.1.) and by other authors (Leaver et al,1968;1986; Bines,1979; Broster and Broster,1984). However, the total ME was reduced in the very low quality feed (Umoh and Holmes,1974).

The quantity of fresh matter has been considered a possible factor affecting the DM consumed, through effects on the rate of passage and/or the water flux (Verite and Demarquilly,1970; Chase,1979;1980). Its possible influence is through the intercellular water content. The calculated concentration of the DM consumed was higher for the supplemented animals. However, it is highly unlikely that at these levels of nutrition with non-lactating cows water had any significant effects.

5.3.4 ME Intake.

The consumption of hay increased the total apparent ME intake by 3.6 MJME per kg hay DM, despite the corresponding decrease in energy consumed as pasture (4MJME per kg hay DM) and the low energy concentration of the hay compared with the herbage. The amount of apparent ME consumed by the LA+ and HA was similar, although the DM intake was different.

Around 33% and 28% of the total apparent energy eaten by the supplemented cows was eaten from hay for the low and high herbage allowance respectively.

The increase in the total apparent ME intake was equivalent to about 47% of the extra ME eaten as hay. This energy increase was also reported by Eldridge and Kat (1980), although they found a higher increase at the higher quality pasture. The same trend was reported by Phillips and Leaver (1985a) for the lower stocking rate.

5.4 SUBSTITUTION BETWEEN FEEDS.

The effect of the supplement on intake of pasture has been calculated by different methods:

$$\text{Substitution Rate(DM)} = \frac{(H\ DMI_{\text{without s}} - H\ DMI_{\text{with s}})}{kgDM_{s}}$$

(Stockdale et al,1981)

$$\text{Substitution Rate(DM)} = \frac{(H\ DMI_{\text{lower s}} - H\ DMI_{\text{higher s}})}{kgDM_{s}}$$

(Meijs,1981)

H DMI = Herbage DM Intake (kgDM/cow)
S = Supplement

For the present discussion Stockdale's way of calculation was utilized always referred to the lower level of supplementation, but not to the immediately lower level as was suggested by Meijs (1981), when there was not a zero supplement group.

The effect of hay supplementation on intake of pasture has also been reported as the substitution rate of metabolizable energy. It was calculated and reported as the change in total ME consumed, due to the intake of 1 MJME as supplement (SME), using Stockdale's method.

The results of a number of experiments have been summarized in Table Nº 5.4.1., mainly for lactating cows, and for a variety of supplementary feeds. The effects of supplementary feeding on feed intake are reported as:

- the decrease in herbage intake
- the increase in total DM intake
- the increase in total ME intake

The results of the present data lie approximately in the middle of the wide range of data.

Table Nº 5.4.1. Reduction in Intake of Pasture per Unit Of Additional Supplements expressed in kg/kgDM or MJME/MJME given to different grazing animals.

Reference and Brief Experimental Details	Supplement Consumed daily cow/day	Effect of Supplement on Feed Intake: Change in Herbage DM Consumption: kgDM/kgDM as Supplement	Change in Total Feed Consumed: kgDM/ kgDM as Supplement	MJME/ MJME as Supplement
Hay				
Present Experiment	5.0	-0.28	+0.72	+0.54
Non-lactating cows	5.0	-0.40	+0.60	+0.35
Eldridge and Kat,1980	2.1	-0.1	+0.9	+0.76
Non-lactating cows	2.4	-0.5	+0.5	+0.38
Stockdale et al,1981	5.0	-0.54	+0.46	+0.35
Early Lactation	7.0	-0.27	+0.73	+0.69
Phillips and Leaver,	1.5	-0.4	+0.6	+0.47
1985a Whole Lactation	1.3	-0.15	+0.85	+0.80
Two stocking rates	1.7	-0.76	+0.24	+0.07
Set Stocked cows	1.5	-0.47	+0.53	+0.43
Hay as Buffer	1.8	-0.22	+0.78	+0.75
	1.6	0.0	+1.0	+0.93
	1.7	-0.47	+0.53	+0.43
	1.5	-0.20	+0.80	+0.75

Table Nº 5.4.1. Continuation

Silage

Bryant,1978 Wilted	8.8	-0.36	+0.64	+0.70
Mid-Lactation	7.8	-0.36	+0.64	+0.70
Bryant and Trigg,1982	2.1	-0.33	+0.67	+0.67
Early Lactation Wilted	4.0	-0.42	+0.58	+0.58
Phillips and Leaver,	-	-1.3	-0.3	-0.5
1985b Early and Late	-	-0.85	+0.15	0.0
Lactation Silage	-	-0.91	+0.09	-0.06
as Buffer	-	-0.68	+0.32	+0.32
Set Stocked	-	-0.73	+0.27	+0.27
Moran et al,1986 Maize	3.0	-0.58	+0.42	+0.37
Silage Early Lactation	3.0	-0.77	+0.23	+0.17

Concentrates

Saker and Holmes,1974	4.0	-0.57	+0.43	-
Non-Lactating Cows	6.0	-0.47	+0.53	-
	8.0	-0.43	+0.57	-
Meijs and Hoekstra,	3.2	-0.06	+0.94	-
1984	3.2	-0.08	+0.92	-
Early Lactation	5.6	-0.09	+0.91	-
Two experiments	5.6	-0.21	+0.79	-
Two Herbage	3.2	-0.37	+0.63	-
Allowances	3.2	-0.79	+0.21	-
	5.6	-0.70	+0.30	-
SuR=-0.48 + 0.039DHA*	5.6	-0.65	+0.35	-

Table Nº 5.4.1. Continuation

Jennings and Holmes,	4.0	+0.41	+1.41	+0.97
1984 Early and Late	5.0	+0.29	+1.29	+0.87
Lactation Different	4.0	+0.15	+1.15	+0.85
concentrate Energy	5.0	0.0	0.0	+0.69
Stockdale and Trigg,	2.0	0.0	0.0	-
1985	4.0	0.0	0.0	-
Late Lactation	6.0	-0.23	+0.77	+0.84
Two Herbage	2.0	-0.94	+0.06	+0.33
Allowance	4.0	-0.43	+0.57	+0.69
	6.0	-0.30	+0.70	+0.79
Arriaga and Holmes,	6.0	-0.36	+0.64	+0.64
1986b Early Lact Two GS	6.0	-0.13	+0.87	+0.86
Meijs,1986 Early Lact.	5.4	-0.45	+0.55	+0.60
High or Low Starch	5.3	-0.21	+0.79	+0.81
Stakelum,1986 Early	4.5	-0.33	+0.67	-
Lact. Two DHA	4.5	-0.68	+0.32	-
Grainger unpublished	3.5	-0.09	+0.93	-
Early Lactation	3.5	-0.25	+0.75	-
Three DHA	3.5	-0.69	+0.31	-

Table Nº 5.4.1. Continuation

Others

Umoh and Holmes,1974	-	-0.71	+0.29	-0.33
Beef Cattle	4.0	-0.52	+0.48	+0.55
Straw, Molasses,	3.0	-0.33	+0.67	+0.74
Sugar beet pulp	3.0	-0.66	+0.34	+0.40
	6.0	-0.78	+0.22	+0.35
Vadiveloo and Holmes,	2.2	-0.83	+0.17	+0.26
1979 Two GS	1.9	-0.75	+0.25	+0.12
Barley, Lucerne cobs,	2.1	-0.61	+0.39	+0.41
Concentrate mixture	2.0	-0.51	+0.49	+0.51
	2.0	-0.44	+0.56	+0.53

DHA=Daily Herbage Allowance
DHA*=DHA (kgOM/cow/day) above 4 cms.
GS=Grazing Systems
Lact=Lactation
SR=Stocking rate
SuR=Substitution Rate

5.5 PREDICTION OF DM INTAKE.

It is important to know the intake of food in order to adjust the level of nutrition to the particular circumstances. Different equations developed in different environments and with different kinds of feed have been used to predict the intake of cattle, but due to the large number of factors involved in the control of intake (Bines,1971; Hodgson,1977; Forbes,1986) those equations are specific for the conditions with high variation when they are tested in different environments (Hoogendoorn,1987) or for different kinds of foods (Neal et al,1984).

Generally, the information available is estimated from lactating cows fed with mixed diets indoors (Bines et al,1977; NRC,1978; ARC,1980; MAFF,1984), or grazing (Meijs and Hoekstra,1984; Stockdale,1985; Caird and Holmes,1986). Those equations assumed that the intake of the non-lactating cow maintains similar relationships except for the change of level of intake related to the level of milk production and the generally accepted fall in consumption as parturition approaches, starting during the last six weeks (Journet and Remond,1976; Meijs,1981). This reduction in intake is associated with possible physical, hormonal or metabolic mechanisms.

In the regression calculated in the present experiment (Section Nº 4.1.2) daily herbage allowance and the quantity of hay offered explained approximately 68% of the proportion of the variance of total DM intake.

There is no information available for non-lactating or lactating cows supplemented with hay. Herbage allowance has been utilized to predict herbage intake (Meijs,1981; Meijs and Hoekstra,1984; Stockdale,1985; Caird and Holmes,1986) for grazing lactating cows. The level of supplementation has been accepted as a variable affecting the total DM intake in several experiments (Table Nº 5.4.1.). Hence, it has been used to predict the intake of grazing cows (Meijs and Hoekstra,1984; Stockdale,1985; Caird and Holmes,1986). The increase in total DM intake caused by an increase in herbage allowance, predicted from the present data, was 0.61 kgDM for an extra 1 kg herbage DM offered. This is higher than the 0.15 to 0.35 reported for lactating cows at higher herbage allowances (Stockdale and King,1980; Stockdale,1985).

The residual herbage mass has been used successfully as a predictor of herbage intake (LeDu et al,1979; Holmes and McClenaghan,1980; Stockdale and King,1984; Stockdale,1985; Bryant and Holmes,1985; Holmes,1987; Poppi et al,1987), and from a practical point of view it is very useful because of its simplicity. However, RHM is less reliable as a predictor of DM intake than herbage allowance. In the present work RHM and hay consumed explained about 49% of the variance of total DM intake. An increase in RHM of 1 ton DM/ha was associated with an increase of 3 kgDM in the total intake of the cows. This figure agrees with that of Stockdale (1985) who reported between 3.2 and 5.2 kgDM for lactating cows.

The calculated regressions (Section Nº 4.1.2.) were good predictors of DM intake at the low or moderate allowance offered by Holmes and McClenaghan (1980), but overestimated the intake at the high or very low level or for the intakes reported by Nottingham (1978). This could be related to the influence of environmental conditions on the cutting technique during the winter season.

5.6 CHANGES IN LIVEWEIGHT AND CONDITION SCORE.

5.6.1 Effect of Herbage Allowance.

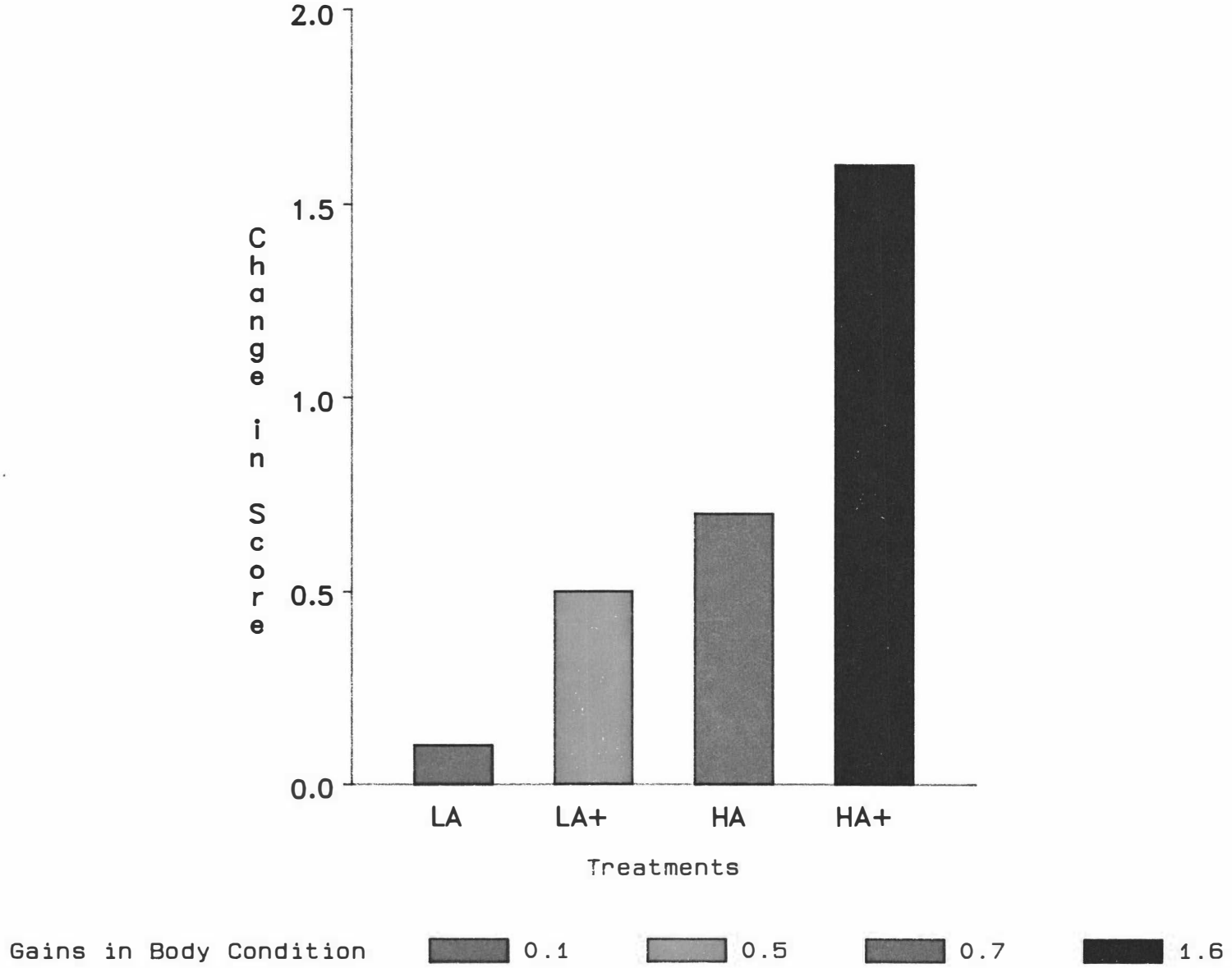
Final Liveweight and Liveweight Gains The final liveweight (adjusted for initial weight) was increased by 15.4 kg by the higher herbage allowance (Table Nº 4.2.1), in agreement with the results reported by Hutton and Parker (1973), Nottingham (1978), Holmes and McClenaghan (1980) and Ngarmsak (1982), for non-lactating cows during the winter. That increase in liveweight is related to the higher DM or ME consumed.

Net Liveweight Gains The 'net' liveweight gain gives a better estimate of the feeding value of the diet, because it removes the effects of change in weight of the gravid uterus. The importance of the maternal weight is related to the future milk production of the cow if the body reserves are considered as carryover effects available in early lactation (Bines,1979; Broster and Thomas,1981; Grainger and McGowan,1982).

Body Condition Score It is suggested that the body condition score can be a better estimate of the body reserves than would be provided by measurement of the liveweight (McMillan and Bryant,1980; Scott et al,1980; Gray et al,1981; Holmes et al,1981; Grainger and McGowan,1982).

The final body condition score adjusted for initial body condition and the change in body condition score were increased by the higher herbage allowance (Table Nº 4.2.2.). The change in body condition score during the experiment is shown in figure Nº 5.6.1.

Figure 5.6.1 Gains in Body Condition over 42 days (Score/cow)



5.6.2 Effect of Hay Supplementation.

Final Liveweight and Liveweight Gains The hay supplementation increased the final liveweight by 10.5 kg (Table Nº 4.2.1.). Similar trends have been described by Campbell and Clayton (1966) for non-lactating cows or lactating cows (King and Stockdale,1981,1982; Phillips and Leaver,1985a) supplemented with hay.

However, the partial efficiency with which body tissue is synthesised is apparently higher in the lactating cow than in the dry cow (Moe et al,1971; Van Es,1975; Tyrrell,1980), so the comparisons with animals in lactation had some limitations.

Body condition score The final body condition score adjusted for initial body condition and the change in body condition score was increased by hay supplementation (Table Nº 4.2.2.).

However, in the present study the relationship between condition score and calculated maternal liveweight gain had a higher variability (See Appendix 4.2.2) than with the final liveweight. Grainger (1985) suggested that a cow which does not change in body condition score is also in zero maternal energy retention. However, for the present experiment the cows in LA maintained the body condition, despite a small decrease in maternal liveweight. The cows allocated to the HA+ group gained on average only 1.6 kg calculated maternal liveweight more than the HA cows, but gained 0.9 more body condition score during the same experimental period. This can probably be explained by inaccuracies in the technique of scoring (Grainger and McGowan,1982). The overall condition score of the cows in all the groups was higher than the 5.0 score suggested by Bryant (1985) as that recommended for calving.

5.6.3 Interaction between Herbage Allowance and Hay Supplementation.

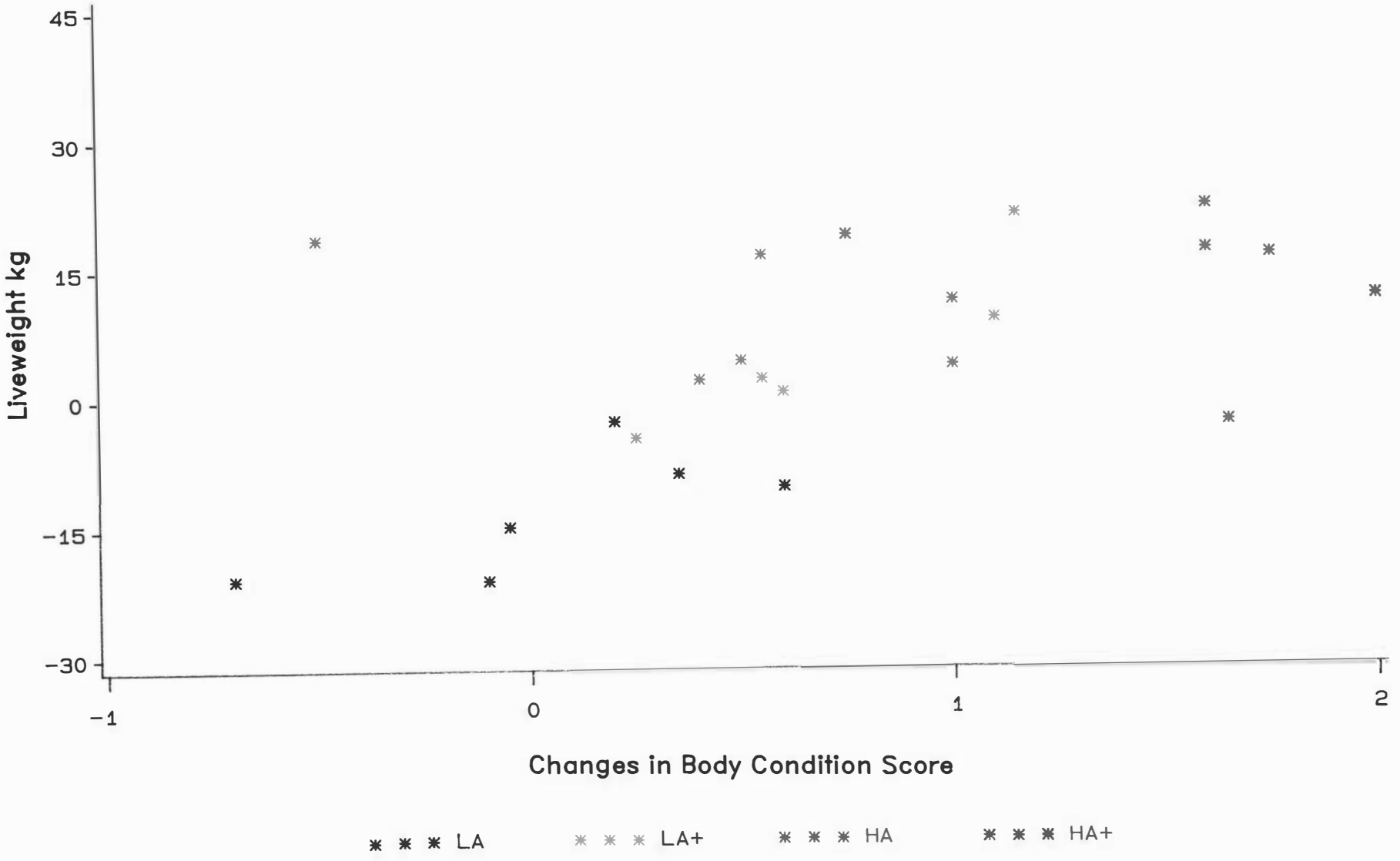
The interaction between hay supplementation and herbage allowance was not significant for all the animal characteristics, except for 'net' liveweight gains.

Net Liveweight Gains The 'net' liveweight gain or the change in calculated maternal liveweight without the estimated weight of the gravid uterus had a different behaviour from the liveweight gain (Figure Nº 5.6.2).

There was a significant interaction between the effects of herbage allowance and of hay supplementation, 'net' liveweight gain being higher for the LA+ compared with the LA, but lower for the HA+ group than the HA group.

This effect was probably related to the mechanism of control of food intake at the high herbage allowance that could be affected by the hay supplementation (Section 5.3.2.), and also because of a higher partial efficiency of body gain (k_g) of the pasture compared to the supplemented cows due to the low quality hay (ARC,1980; MAFF,1984). However, there was a 12 days difference in the gestation time between the HA+ and the HA. It is important to bear in mind that during this time of gestation the growth of the foetus is exponential, probably masking the effects.

Figure 5.6.2 Relationship between Changes in Maternal Liveweight and in Body Condition Score



5.6.4 Relationship between Liveweight gain and Condition Score

The relationship between liveweight gain and condition score was 21.5±11.8 kg liveweight gained per 1 condition score gained (Figure Nº 4.2.1.).

This average was in agreement with the 21.0kg reported by King and Stockdale (1981), but lower than the values reported by Nottingham (1978) (44.1kg/CS), Bryant and Cook (1980) (33 kg/CS), McMillan and Bryant (1980) (17kg/CS free foetus) for Jersey cows, Holmes (1981) (35kg/CS), Grainger et al (1982) for FriesianxJersey cows (34kg/CS),, King and Stockdale (1982) (33.2kg/CS), Ngarmsak (1982) (26kg/CS), Grainger et al (1985) (43.8kg/CS) and Fulkerson et al (1986) (40kg/CS).

5.6.5 Estimates of Maintenance Requirements

The requirements of energy to maintain maternal liveweight are shown in Table Nº 5.6.1., with the requirements proposed by other authors.

Table Nº 5.6.1. Estimated requirements of Maintenance.

Reference	Requirement MJME/$kg^{0.75}$	Pregnancy month	Observations
Present Study	1.02	8_{th}	Grazing
Holmes and McClenaghan (1980)	1.02	7_{th}	Grazing
ARC (1980)	0.60	8_{th}	Several Sources, Calorimetric
Ngarmsak (1982)	0.67	8_{th}	Grazing
MAFF (1984)	0.63	8_{th}	Grazing
Holmes and Grainger (1982)	0.74	7_{th}	Indoors
Grainger et al (1985)	0.79	8_{th}	Calorimetric,HBI
	0.80	"	Low Breeding Index

The value observed in the present experiment was in accordance with the requirements proposed by Holmes and McClenaghan (1980) for lighter animals, but higher than those reported by ARC (1980), Ngarmsak (1982), Holmes and Grainger (1982), MAFF (1984) and Grainger et al (1985). The difference in maintenance requirements between the present experiment and those calculated from calorimetric chambers indoors (ARC,1980) was 38%, higher than the 25% suggested by Holmes and Grainger (1982) for indoor cows. The effect of the before after cutting technique to estimate the herbage DM consumed could

overestimate the values due to the wet conditions that made it difficult to cut the RHM accurately.

The estimated ME intake of the cows was probably overestimated by the before-after cutting technique compared with the animal performance observed, as is shown in Table Nº 5.6.2.

Table Nº 5.6.2. Comparison between Total Apparent ME Intakes calculated from the Measurement of Herbage Masses, and Theoretical ME Intakes calculated from the animal performance measurements.

	LA	LA+	HA	HA+
"Measured" ME Intake	93	114	121	135
ARC (1980)[1]	57	78	82	88
Theorical ME Intake[2]	83	106	110	116

Using data for requirements from: [1] ARC,1980 and
[2] Grainger and Holmes (1982) (Animal Performance Technique)

Amount of ME to Gain Condition Score The amount of ME calculated to gain one C.S. was 1197 MJME/CS, similar to and in the middle range of the previous data (875 - 1386). Holmes and Grainger (1982) (1128 MJME / CS); ARC (1980) (875 MJME/CS) or Gray et al (1981) (977 MJME /CS) for indoor cows, or Ngarsmak (1982) (1302 MJME/CS) and Holmes and McClenaghan (1980) (1386 MJME/CS) for grazing cows.

The low ME calculated needed to gain one body condition score in the present study compared with other grazing experiments was mainly affected by the high gain in C.S. of

the HA+ group, but not by the high body condition observed in the study. This difference was probably related to the variability of the condition score technique (Grainger and McGowan,1982).

5.7 WATER INTAKE.

The sources of water to fulfil the water requirements of animals are the water which is drunk, the water which is consumed with the feed (in and on), the water in inspired air (Nicholson,1985), and water formed within the body as a result of oxidation of organic compounds (Leitch and Thomson,1944; ARC,1980). As was shown in the materials and methods the last two sources of water were not taken into account for the present experiment

5.7.1 Water Drunk.

Hay supplementation increased the quantity of water drunk (Table Nº 4.2.3.). However, the interaction between herbage allowance and hay supplementation was significant.

The correlation between hay supplementation and water drunk has been observed by several authors and summarized by More and Sahni (1981) and Stockdale and King (1983).

The increase in quantity of water drunk by the cows given hay supplementation was higher at the low allowance (13.0 l) compared with the high herbage allowance (7.0 l). This could be related to the higher proportion of hay DM in the total DM consumed for the low allowance (43%) compared with that at the high herbage allowance (37%). This interaction between herbage

allowance and supplementation was not found by Stockdale and King (1983) with lactating cows supplemented with hay probably due to the reduced number of cows in each group and the fact that the pasture offered had a higher DM content (% DM) which could have masked the dilution effect observed in the present study.

The quantity drunk per cow (Table Nº 4.2.3.) for the unsupplemented cows was similar to the 14 l reported by Wright and Jones (1974) during the winter in New Zealand and Castle and Watson (1973) for non-lactating grazing Ayrshire cows.

The quantity of water drunk by the supplemented cows was higher than the values reported by Wright and Jones (1974) for lactating cows producing between 7 - 11 l per day.

5.7.2 Water Ingested with Pasture.

The quantity of water ingested with pasture was inevitably associated with the herbage intake. Therefore the supplemented groups consumed less water in this form than the unsupplemented cows, because of the effect of supplementation on herbage intake (Section 5.3.2). Also because the level of allowance affected the amount of pasture intake, the high allowance groups ingested significantly higher water from the pasture.

5.7.3 Total Apparent Water Consumed.

Effect of Herbage Allowance The total apparent water consumed (water contained in the feed + water drunk) was influenced by the herbage allowance, related to the level of pasture intake. The total water consumed was increased by 13 l at the higher allowance.

The water ingested with the pasture constituted 82%, 62%, 82% and 72% for the LA,LA+,HA and HA+ respectively, showing the importance of the water drunk for the supplemented cows to reach their total water intake. As a percentage of the total water consumed, the water drunk by the unsupplemented cows was similar to the 18% described by Castle and Watson (1973) for lactating cows grazing pastures of perennial ryegrass. However, this relative input of the drinking water over the whole water consumed is influenced by several factors e.g. temperature (Cowan et al,1978; Stockdale and King,1983); type of diet (Leitch and Thomson,1944; Castle,1972) and availability (Campbell,1958; King and Stockdale,1981; Nicholson,1985).

Effect of Hay Supplementation The large increases in water drunk (2.1 and 1.5 fold) by the supplemented cows did not increase the total water consumed. This apparent anomaly occurred because of the effect of supplementation on the consumption of herbage, and on the associated water ingested with the herbage.

The total water consumed was not affected by the hay supplementation, showing that the drinking water was the buffer to reach the levels of water required by the supplemented cows. In addition the quantity of water consumed by the cows at the high allowance without supplement was slightly higher than for those at the high allowance with hay. Probably showing that those cows consumed more water than they required as was

suggested by Castle and Watson (1973), Cowan et al (1978) and King and Stockdale (1981) for lactating cows in temperate or tropical conditions. There was no increase in total water consumption at the low allowance, probably due to the low level of feeding.

The lack of any significant effect of hay supplementation on water consumed disagreed with the results of Stockdale and King (1983) for lactating cows. Their cows at a higher herbage allowance consumed more water than in the present study. The difference with the supplemented cows could be explained by the fact that in their experiment the ratios of hay:pasture were higher than in the present study and the DM substitution rate was lower than the level reported in the present study and also the DM content of the pasture was lower.

Bearing in mind that the present experiment was done under a mean temperature of 8 °C with non-lactating pregnant cows, the absolute values of total water consumed were higher than the quantities for lactating cows supplemented with hay (Stockdale and King,1983), or grazing cows during the winter in New Zealand (Wright and Jones,1974). The high quantities of total water consumed reflected the high herbage fresh matter intake with high moisture content.

5.7.4 Relationship between Water and DM Intake.

Water drunk The quantity of water drunk per kg total DM consumed was significantly increased by supplementation with hay, in accordance to the results of Stockdale and King (1983). However, the amount of water drunk per kg DM eaten in the present experiment was higher than that reported by those authors.

The amount of 'extra' water drunk per kg hay DM intake is defined as:

$$\text{'Extra'} = \frac{\text{Water Drunk}_s - (\text{Water Drunk}_u / \text{kgHDMI}_u) * \text{kgHDMI}_s}{\text{kg Hay DM}}$$

'Extra'='Extra' Water drunk per kg hay DM eaten
Water Drunk_s=Water drunk by the supplemented group
Water Drunk_u=Water drunk by the unsupplemented group
kgHDMI=kg herbage DM intake

It was higher at the low allowance than at the higher allowance (Table Nº 4.2.4.) reflecting the higher proportion of hay in the whole diet, and consequently a lower dilution effect.

For practical conditions the additional water drunk by the cows allocated to the supplemented groups was 2.6 and 1.4 l/kg hay DM eaten for the low and high herbage allowance respectively.

Total water consumed The total apparent water consumed was decreased by 2 l/kg DM eaten by supplementation with hay (Table Nº 4.2.4.), but the effect of herbage allowance was not significant.

The relationship between the total DM intake and the total amount of water consumed reported by Castle and Watson (1973) and Castle and Thomas (1975) was not observed in the present experiment due to the utilization of hay. Hay supplementation increased the quantity of water drunk but did not supply enough water with the diet to maintain the high ratio water/kgDM clearly observed in the unsupplemented cows.

The total water consumed per kg DM eaten by the supplemented cows was similar to the values reported by ARC (1980) for non-lactating cows but slightly lower than the values observed for the unsupplemented cows. It is important

to bear in mind that the comparison with lactating cows has several limitations, because the lactating cow has a different turnover rate of water (Wright and Jones,1974; Castle and Watson,1973), different metabolic rates, different DM intakes and consequently larger quantities of metabolic water, as well as other differences.

The higher values observed in the present experiment could not be explained by the fluctuations in air temperature nor the type of animal, but probably they were related to the herbage intake measuring technique (Section Nº 5.2.2.) that could overestimate not only the apparent DM intake but also the estimated water ingested with the pasture (Table Nº 4.2.3.).

It is suggested that the equations developed for lactating cows (Castle and Thomas,1975; ARC,1980; Lanham et al,1986) corrected for milk yield overestimate the water drunk by non-lactating pregnant cows and do not consider the important component of type of diet.

5.7.5 Environmental Conditions.

The influence of the environmental conditions on the water turnover and water requirements had been recognized for a long time. Rainfall, relative humidity, minimum temperature and wind speed had a negative effect on the quantity of water drunk during the present study. However, sunshine hours had a positive influence over the water drunk (Table Nº 4.2.5.).

Rainfall The negative effect of rainfall on water drunk recorded in the present experiment (Table Nº 4.2.6.), was also reported by Castle (1972), Castle and Watson (1973), Castle and MacDaid (1975) and Stockdale and King (1983) for temperate conditions and Payne (1966), Cowan et al (1978) and Nicholson (1985) for tropical conditions. The effect of the rainfall can

be related to a lower evaporation rate, higher water consumed with the pasture or lower water turnover.

Relative Humidity The negative effect of relative humidity on water drunk, recorded in the present experiment, was also reported by Castle and Watson (1973) at similar air temperatures to the present study, Castle (1972) during the summmer, Cowan et al (1978) and Stockdale and King (1983) under tropical conditions. However, Castle and Thomas (1975) did not find an effect of relative humidity on water drunk.

Temperature The non significant effect of mean and maximum temperature (Table Nº 4.2.6.) over water drunk was in agreement with the reports of Castle and Thomas (1975) and Stockdale and King (1983), but contrary to that observed by Castle and Watson (1973), Castle and MacDaid (1975), Cowan et al (1978) and Murphy et al (1983). The negative correlation observed between minimum temperature and water drunk was also found by Stockdale and King (1983) and Murphy et al (1983).

The negative correlation between wind speed and water drunk was also reported by Stockdale and King (1983). Unfortunately, there are not many studies that consider those environmental factors in their analysis.

Sunshine The positive correlation between sunshine hours and water drunk (Table Nº 4.2.6.), was also reported by Castle and Watson (1973), Castle and MacDaid (1975), Cowan et al (1978), Stockdale and King (1983) and Nicholson (1985). The increase in water drunk associated with hours of sunshine can be related to the increase in evaporative water loss.

5.8 ANIMAL BEHAVIOUR.

5.8.1 Rate of Biting.

The rate of biting during the first three hours on the fresh pasture given each day (Table Nº 4.2.7.) declined rapidly after the first hour, following the same trend described by Stobbs (1974), Jamieson and Hodgson (1979) and Phillips and Leaver (1986).

The values observed in the present experiment were within the range reported by Jamieson (1975) for calves or lactating cows, but lower than the values recorded by Stobbs (1974), Chacon et al (1976) for non-lactating cows, Forbes and Hodgson (1985) and Phillips and Leaver (1986) for grazing cows, and higher than the values reported by Hancock (1954). It is important to bear in mind that those values are reported as the mean of 24 hours or of several observations but not necessarily consecutive. There are not many data for rate of biting for non-lactating cows at low feed allowances. It has been suggested that the decrease in rate of biting is related to the limitations imposed by the sward when the herbage mass declines (Allden and Whittaker,1970; Hodgson and Jamieson,1981).

The coefficient of variation of the rate of biting for the four groups of cows was higher than the values reported by Hodgson (1982b) (8 - 12%). The values for the C.V. for the first 30 minutes in the new strip were between 17 - 21%, with the tendency to increase thereafter. Some of this variation can be related to the rapid reduction in pasture present for the low herbage allowance groups and consequently the individual effort of the animal to try to compensate for the low intake per bite. However, there was also high variation in the high herbage allowance groups, showing high variability

between animals.

Effect of Herbage Allowance There was an increase in the rate of biting by the cows allocated to high herbage allowance compared to the low herbage allowance groups (Table Nº 4.2.7.). This increase was maintained during the first three hours after the cows were allocated to a new strip.

Effects of herbage allowance on rate of biting appear to be inconsistent between different experiments.

The present results agree with the data reported by LeDu et al (1979) for lactating cows, but disagree with the data of Jamieson and Hodgson (1979) for calves. The rate of biting was higher for the high stocking rate than for the low stocking rate for large animals continously stocked (Zoby and Holmes,1986).

Effect of Hay Supplementation The supplemented groups had a higher rate of biting during the first three hours after the cows were allocated to a new strip (Table Nº 4.2.7.).

The increase in rate of biting of the supplemented groups during the first hour can be explained partially as a compensatory effect due to low intake per bite.

However, the possible reasons for this effect are not completely clear, and previous reports are inconsistent. Phillips and Leaver (1986) observed that in continuously stocked animals the rate of biting slightly increased through the day using hay or silage as buffers for lactating cows during early or late lactation. There was no increase in biting rate to try to compensate for the reduction in bite size. Jennings and Holmes (1984) observed a depression in rate of biting of the low quality concentrate compared with the control during late lactation, but not during early lactation.

5.8.2 Herbage Intake per Bite and Total Herbage Intake during the First Hour.

Effect of Herbage Allowance The total apparent herbage intake during the first hour was similar (approx. 5 kgDM) for all four groups. Intake per bite during the first hour was not affected by the herbage allowance (Table Nº 4.2.8.).

Despite the limitations of the methods utilized, the quantity eaten per bite during the first hour was similar to the values reported by Jamieson and Hodgson (1979), but lower than the mean reported by Stobbs (1973), Chacon et al (1976), LeDu et al (1979), Jennings and Holmes (1984) and Forbes and Holmes (1986). Zoby and Holmes (1986) reported a higher intake per bite at the lower stocking rate than at the higher stocking rate.

Effect of Hay Supplementation Intake per bite was decreased by supplementation with hay at both allowances (Table Nº 4.2.8.).

Contradictory effects of supplementation on intake per bite have been reported by Phillips and Leaver (1986), who found no significant effect when offering hay, an increase in bite size by offering silage overnight, but a significantly lower bite size when cows were offered silage during late lactation. They estimated rate of biting indirectly from the herbage intake divided by the number of bites, increasing the accumulate error.

5.8.3 Grazing Behaviour during Daytime.

It is important to note that all other events were mutually excluded when one event was recorded. It is important to note that the present data refer to activities between dawn and dusk, when most but not necessarily all grazing takes place (Hodgson,1982b; Stockdale and King,1983).

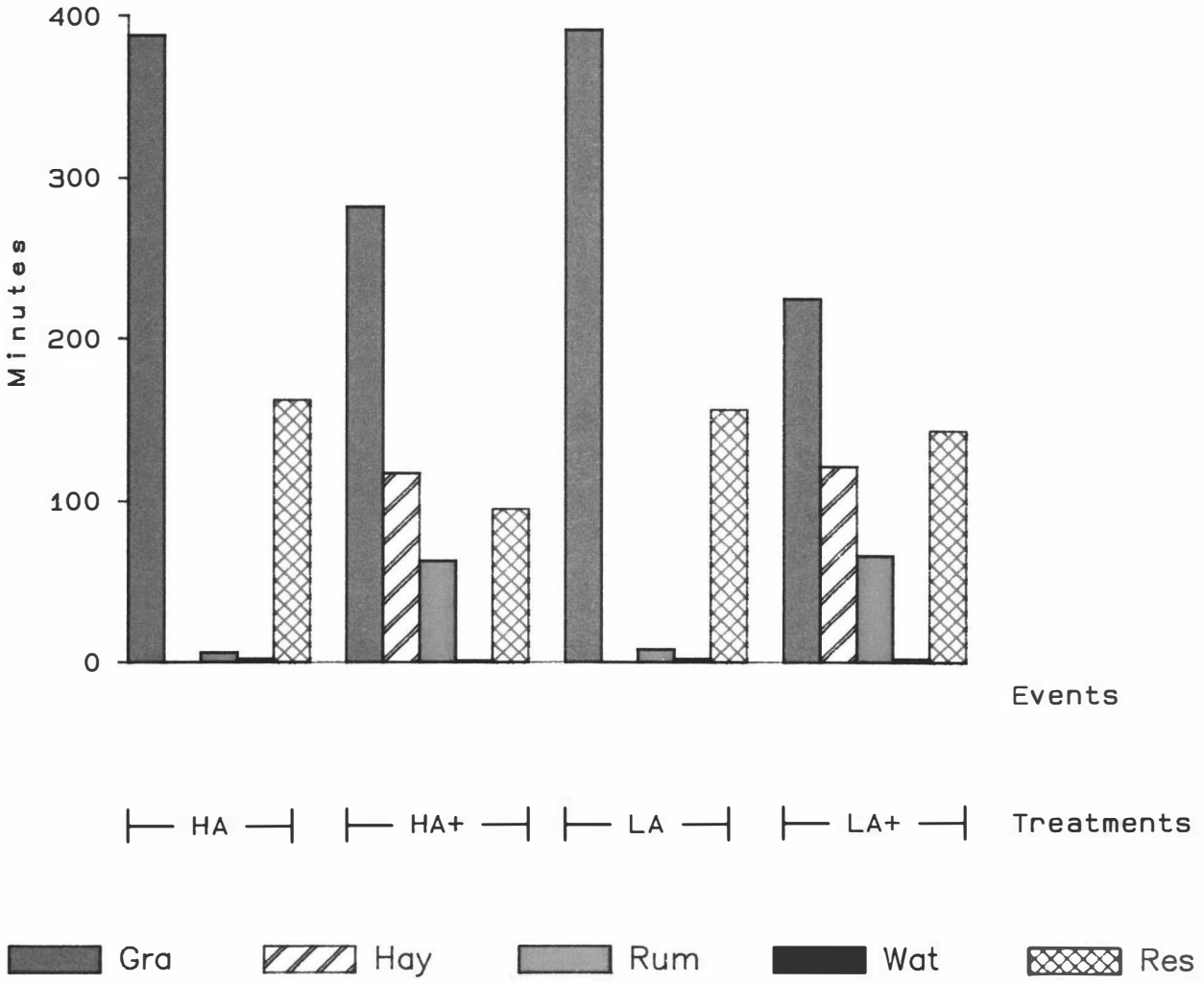
The time spent grazing during the daytime (Figure Nº 5.8.1) was higher for the unsupplemented groups than the time recorded by Cowan (1975) during summer or winter, but lower for the supplemented cows. Nevertheless the values of the supplemented cows were higher than the values observed during the second experiment by Cowan (1975) for cows unsupplemented or supplemented with maize.

Brumby (1959) reported a mean of 7 hours and 28 minutes grazing for non-lactating cows in New Zealand during 24 hours, being higher than the values observed in the present study during daylight. However, in his experiments the effect of silage supplementation has a confounded effect.

The rate of eating the hay was within the 2 - 3 kgDM/hour reported by Phillips and Leaver (1985a;1985b) for supplementation with hay or silage.

Effect of Herbage Allowance The herbage allowance did not influence the time spent in grazing, ruminating, resting or drinking water during the hours of daylight (Figure Nº 5.8.1), contrary to the curvilinear response between grazing time and herbage allowance reported by Stockdale and King (1983). They also observed an increase of 0.03 hours per kg herbage allowance offered.There is limited information for behaviour for non-lactating cows during daylight hours.

Figure 5.8.1 Behaviour during Daytime



Gra=Grazing; Hay=Eating Hay; Rum=Ruminating; Wat=Water;

Res=Resting

Effect of hay Supplementation The time that the cows spent grazing during the daytime was reduced by hay supplementation, but ruminating time was significantly increased (Figure Nº 5.8.1).

Hay supplementation reduced grazing daytime by about 27minutes/kg hay DM and increased the ruminating time 11 minutes/kg hay DM. The quality of the diet can have a large influence over the time of ruminating (Hancock,1954; Dulphy et al,1980; Van Soest,1982) and also the physical nature of the diet (Bell,1984). Apparently the low quality of the hay used in the present experiment depressed the time spent grazing, but increased the time spent ruminating. This possible change in the grazing time could influence the time the cows spent selecting the pasture to consume and consequently reducing herbage intake. Bearing in mind that the values reported by other authors are recorded over 24 hours, some published data are summarized in Table Nº 5.8.1.

Table Nº 5.8.1 Effect of Supplementation on change in Grazing Time (GT) expressed in minutes per kgDM consumed as supplement.

Reference and Brief Experimental Details	Decrease in GT caused by supplement min/kgDM	Supplement fed Quantity kgDM/ cow daily	Type
Non-lactating			
Present Study	27[1]	5	Hay
Sarker and Holmes,1974	33	4	Concentrate
"	22	6	Concentrate
"	23	8	Concentrate

Table Nº 5.8.1 Continuation

Reference and Brief Experimental Details	Decrease in GT caused by supplement min/kgDM	Supplement fed Quantity kgDM/ cow daily	Type
Lactating			
Cowan,1975	19	4.5	Maize
Journet and Demarquilly,1979	15-20	-	Concentrate
Jennings and Holmes,1984	8	4	Concentrate
Supplement quality	12	4	Concentrate
Phillips and Leaver,1985a	21	1.7	Hay
Two stocking rate	4	1.5	Hay (Buffer)
Phillips and Leaver,1985b	25	1.7	Silage(Buffer)
Early and Late Lactation	45	4	Silage
	38	10.3	Silage
availability	26	4	Silage
	32	10	Silage
Arriaga and Holmes,1986b	11	6	Concentrate
Grazing System	9	6	Concentrate

[1]=Daylight time

Table Nº 5.8.1 shows that the present depression in grazing time due to hay supplementation was within the range reported by other authors for non-lactating or lactating cows . The increase in rumination time associated with hay supplementation was lower than the values observed by Phillips and Leaver (1985a;1985b) for supplementation with silage or hay at high stocking rates (14 - 21 min/kg DM supplement), but higher than the 4 min/kg hay DM observed for the low stocking rate.

The change in behavioural events during the daytime could play an important role when a supplement of low quality is offered as a supplement for grazing cows, due to reduction in the time the animals spent grazing on the high quality feed, pasture.

5.9 CONCLUSIONS

The quantity of residual herbage mass, herbage intake, and apparent total DM or ME intake was increased by the higher herbage allowance.

Hay supplementation increased the residual herbage mass at both herbage allowances. The consumption of herbage was decreased, but total DM intake was increased by hay supplementation. However, because the hay was of lower quality than the pasture, the net result of the decrease in pasture consumption, associated with consumption of hay, was a smaller increase in ME than in DM intake.

Total DM intake was increased by 0.7 kgDM for each kgDM consumed as hay. Total ME intake was increased by 0.5 MJME for each MJME consumed as hay.

Cows allocated to the higher herbage allowance gained more liveweight and body condition than those cows allocated to the lower herbage allowances.

Cows supplemented with hay gained more liveweight and body condition score than cows not supplemented.

Water drunk was increased by hay supplementation, however, the total quantity of water consumed was similar to the unsupplemented animals. The extra water drunk per kg hay DM intake was higher at the low than at the higher pasture allowance.

Cows supplemented with hay increased the time spent ruminating during daytime, and decreased the grazing time compared with the unsupplemented cows.

These aspects are very important to be considered when hay is used as a supplementary feed.

APPENDICES

Appendix Nº4.2.1 Individual change in Liveweight and Body Condition Score over 42 days of the Experimental Period.

Cow	Liveweight (kg)	Body Condition (Score)
Low Allowance		
157	3	-0.1
161	8.5	-0.05
172	20	0.2
205	13.5	0.35
207	2.5	-0.7
Low Allowance + Hay		
156	28.5	1.1
162	44.5	-0.5
192	13	0.25
212	22.5	0.6
214	43	1.15
218	19	0.55
High Allowance		
152	65	0.8
164	22	0.5
167	20.5	1.0
200	32	1.0
217	24.5	0.4
219	38.5	0.55

Appendix Nº 4.2.1 Continuation

High Allowance + Hay

155	33.5	2.0
174	41.5	0.75
178	20.5	1.65
181	33.5	1.6
215	46.5	1.6
216	36.5	1.75

Appendix Nº 4.2.2 Regression equation between Maternal Liveweight Gains and Body Condition Score.

The relationship between the liveweight gain and the body condition score gain is shown in the regression equation:

$$N.L.W.G. = -2.16 \underset{(\pm 4.10)}{} + \underset{(\pm 0.41)}{1.10\ G.B.C.S.}$$

$$R^2 = 0.2409,\ P < 0.01,\ C.V. = 247\%$$

N.L.W.G.=Net liveweight gain (kg)
G.B.C.S.=Gain in body condition score (units)
C.V. =Coefficient of variation

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