THE COMPARISON OF PASTURE AND CONCENTRATES AS EARLY-WEANING FOODS FOR CALVES

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

MALCOLM JAMES BYFORD

1974

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ABSTRACT

Fourteen Friesian bull calves, born May 1972, were used in an experiment to study the use of pasture compared with concentrates as an early weaning food for calves. Early-weaning was defined as the weaning of calves off a liquid diet to a solid diet by the time they were five weeks of age. The calves were housed indoors in metabolism crates, with the pasture (ryegrass/clover) being cut daily and fed to them fresh. The composition of the concentrate diet was 65% rolled barley, 14% meat meal (60% protein), 15% linseed meal, 5% molasses, and the balance minerals and vitamins. The concentrate diet was fed as a meal and to help ensure the health of the calves receiving it, 10% finely chopped hay was added.

The calves were randomly allocated to the two groups (seven calves in each) on arrival, when they were about four days old. During the pre-weaning period all calves were managed similarly and fed in accordance with early-weaning practise, i.e. restricted level of milk to induce a rapid development of the intake of solid food. In order to guarantee the ingestion of pasture the level of concentrates fed was restricted. The calves were weaned off milk by five weeks of age.

In the post-weaning period, from five through to eight weeks of age, one group of calves received pasture *ad libitum* and the other concentrate *ad libitum* plus a restricted level of pasture (500g wet matter/day - accounting for 8 to 10% of the total DM intake).

The mean live-weight gains of the pasture-fed calves and the concentrate- fed calves were respectively, 0.42 $\pm$ 0.03 and 0.40 $\pm$ 0.03 kg/day pre-weaning and 0.32 $\pm$ 0.01 and 0.58 $\pm$ 0.06 kg/day post-weaning.

It was concluded that pasture was inferior to concentrates in promoting live-weight gain in early-weaned calves. This occurred despite pasture and concentrates having similar DE coefficients; namely 75.16 and 74.25% respectively. The major difference was that of intake, with the calves receiving pasture having a significantly lower DE intake over the post- weaning period compared with the calves receiving concentrates. The difference in intake was probably associated with pasture having a lower bulk density than concentrates. Two possible mechanisms, gut fill and oropharyngeal, whereby this would have caused a difference in intake are discussed. Also discussed is the absolute growth rates of the calves receiving pasture in the context of the possible use of pasture as an early-weaning food for dairy replacement stock.

Between eight and ten weeks the calves receiving the concentrate diet were changed to pasture alone. This caused a decrease in the performance of these calves. However, these results were confounded by a decrease in the quality of the pasture over this period.

Between ten and twelve weeks all calves were receiving pasture alone ad libitum. The rearing methods were shown to have no effect on the calves' intake of pasture during the twelfth week, provided allowance was made for the difference in live weight which existed between the two groups.

The calves were put out to pasture when twelve weeks old and their post-experimental growth rates recorded. This period was terminated when the average age of the calves was 303 days. The results demonstrated that the mean growth rates of both groups during this period were very similar. This resulted in the live-weight difference established between the two groups when they were twelve weeks old being permanent.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the guidance and encouragement of his supervisor for this project, Mr A.W.F. Davey, Dairy Husbandry Department, Massey University. Special mention must also be made of Mr G.C. Jukes, who gave much assistance throughout the running of the trial and later with chemical analysis.

Acknowledgement is also made of:

Members of the Dairy Husbandry Department for their interest in the project and their encouragement during the writing of the thesis

Mr J.S. Wheeler, Dairy Farm Supervisor, who made the calves available

Tasman Vaccine Laboratories who donated the calf food vitamin supplement, used in the concentrate diet.

Finally special acknowledgement must be given to my wife, Anne, both for her moral support and also for typing the thesis.

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INTRODUCTION

It was demonstrated as far back as the 1920's (Meads, Regan and Bartlett, 1924) that calves could be raised successfully when weaned off a liquid food diet onto a solid food diet as early as 30 to 40 days of age. Despite this, traditional beliefs that the calf requires a liquid food diet for at least the first three months of life persisted. However, in the United Kingdom during the 1950's because of increasing economic pressures and a shortage of labour, there was an upsurge of interest in early-weaning as a means of rearing calves. Early-weaning is defined as the weaning of calves from a liquid to a solid food diet by the time they are 35 days of age. This led to the formulation of the "Rowett Early-Weaning System" as proposed by Preston (1957) and later through modification of this earlier concept, to an early-weaning system applicable to New Zealand conditions as proposed by Khouri (1969).

These early- weaning systems have been based on the use of concentrate diets as the solid food onto which the calves are weaned. However, because these foodstuffs are expensive relative to pasture (especially in New Zealand) and also because they are in high demand for the Pig and Poultry Industries, there is pressure to introduce calves to their 'natural' foodstuff, pasture, at an increasingly earlier age.

It is therefore the purpose of this present study to investigate the potential of pasture as an early-weaning food for calves.

CHAPTER ONE

REVIEW OF LITERATURE

The literature is reviewed in three sections:

(i) Control of voluntary intake in young ruminants, shortly after weaning

(ii) Factors influencing the development of solid food intake in young ruminants

(iii) Pasture as an early-weaning food for calves.

1.1. CONTROL OF VOLUNTARY INTAKE IN YOUNG RUMINANTS, SHORTLY AFTER WEANING

The mechanisms whereby the intake of food by ruminants is regulated are highly complex. There are two important concepts relating to the voluntary intake in ruminants. The relationship between these two concepts has been summarized in a model proposed by Montgomery and Baumgardt (1965a) - see Fig. 1.1.

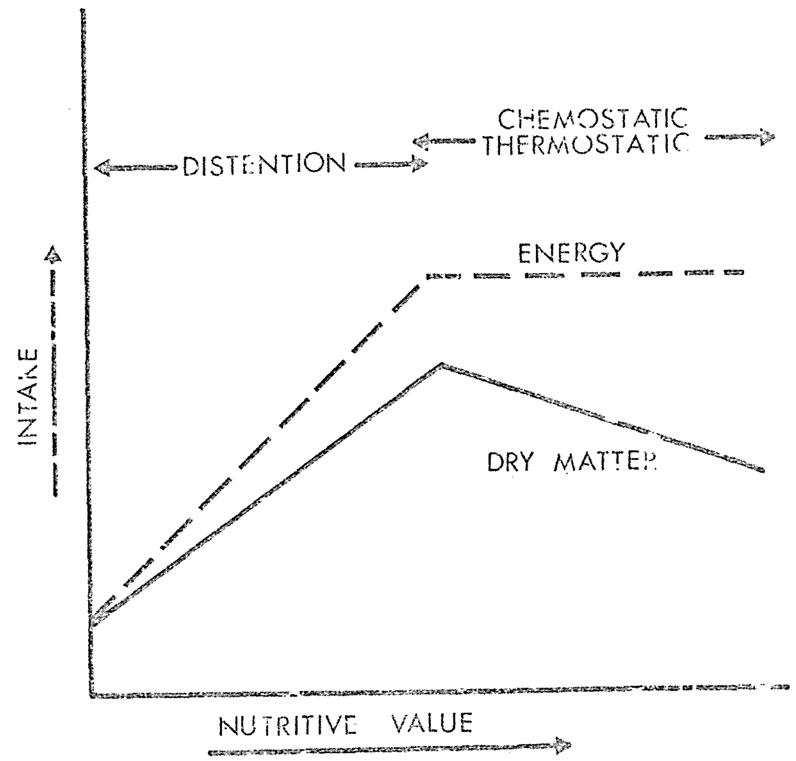


FIGURE 1.1. Probable relationships between energy and food intake and controlling mechanisms. From Montgomery and Baumgardt (1965a)

The first concept involves the extent by which the alimentary tract can accommodate food residues and is represented in Fig. 1.1. by the portion under the distention side. The control of the voluntary intake in ruminants by this means is termed physical control and has been reviewed by Balch and Campling (1962), Campling (1970) and Conrad (1966).

The second concept involves the extent by which absorbed nutrients control intake and is represented in Fig. 1.1. by the portion under the chemostatic, thermostatic side. The control of voluntary intake in ruminants by this means is termed metabolic control and has been reviewed by Baile and Mayer (1970) and Baumgardt (1970).

Thus in a simplified summary, animals receiving a diet of high nutritive value are able to consume enough DM to satisfy their physiological demands for energy, whereas with the low nutritive value foods, rumen load prevents animals from consuming the amount of energy that is physiologically demanded. Such a relationship between intake and nutritive value of food has also been suggested for young ruminants during the post-weaning period (Owen, Davies and Ridgeman, 1969; Andrews, Kay and Ørskov, 1969; Andrews and Ørskov, 1970; Kay, Macleod and McLaren, 1970; Kay, MacLeod and Andrews, 1972; Kang and Leibhloz, 1973).

It is the function of this review, not to attempt to produce an exhaustive account of the control of voluntary intake in young ruminants after weaning, but to highlight recent findings which question whether the mechanisms that have prominence in signalling satiety in adult ruminants, have the same prominence in young ruminants. These findings throw doubt on the validity of the conclusions drawn by the workers mentioned above, that the intake by young ruminants receiving a diet of high DE concentration is controlled by the physiological demand of the animal.

For convenience the discussion is divided into two sections:

(i) Diets, the intake of which is possibly controlled by physical means

(ii) Diets, the intake of which is possibly controlled by metabolic means

It must be remembered that this division is arbitary and that the control of the voluntary intake by physical and metabolic means are not independent; e.g. Egan (1970) stated "that a complex or interacting physical and metabolic factors may be involved throughout the whole range of diets utilized by ruminants, and that there is not simply a switch-over to metabolic regulation at a point where disposal of indigestible bulk is no longer an embarrassment or a limitation to total digestible energy intake."

1.1.1. Diets, the Intake of which is possibly Controlled by Physical Means

The gut is still developing in ruminants that are weaned onto solid food by five weeks of age (see review by Warner and Flatt, 1965). The major change is a rapid increase in the size of the reticulo-rumen relative to empty body weight. This occurs in lambs and calves when they are between two and eight weeks of age, provided solid food is available. This variation in the development of the reticulo-rumen has been suggested as an explanation (Andrews et al., 1969) for the greater ability of the young ruminant with increasing age to equalize intakes of digestible energy from diets differing in energy concentration, as has been shown by Owen et al.,(1969b) Andrews et al.,(1969) and Andrews and Ørskov (1970) working with lambs and McCullough (1969) working with calves. In these experiments the energy concentration of the diets was altered by varying the ratio of the concentrate to hay components and it was noted that the effect of age was more pronounced when the roughage was left unground, than when it was ground. This suggests that the young ruminant shortly after weaning is less able to cope with the bulky nature of the roughage component compared with an older and thus larger animal.

The suggestion that the increase in the size of the rumen may be of importance, is logical in view of the prominent role played by rumen distention as a satiety signal in controlling the intake of older ruminants receiving a roughage diet. However, the evidence is circumstantial, with the difficulty in trying to interpret the role of the development of rumen size in controlling the development of the intake of solid food in young ruminants being that the pattern of the development of these two factors are similar (e.g. Hodgson, 1965; Warner and Flatt, 1965). Therefore, although Hodgson (1971c) was able to demonstrate a significant relationship between DM intake and weight of digesta in the rumen over this transitional phase of the calf's life (transitional phase is the period when the young ruminant is changing from a non-ruminant to a ruminant), such a relationship does not clarify cause and effect.

It was demonstrated by Hodgson (1965, 1971ab) that the intial development of the intake of solid food was related to an increase in the time spent eating, but later increases in the intake of solid food were acheived by an increase in the rate of DM intake per unit of time spent eating with no further increase in eating time. These observations confirmed the results of Swanson and Harris (1958), who worked with Jersey and Holstein calves. No other direct evidence was found in the literature to support this pattern of development, though the results of several experiments with grazing calves (Roy, Shillam and Palmer, 1955; Chambers, 1959; Godfrey, 1961; and Stewart, 1961) may be interpreted in the same way.

This led Hodgson to postulate that in the young ruminant, the intitial development of the intake of solid food may be limited primarily by behavioural factors (Hodgson, 1971a) and that the gut development was dependent on the intake of solid food and not the reverse (Hodgson, 1971c). To test this postulate he utilized a technique first described by Campling and Balch (1961), in which food or digesta are added to or removed from the rumen <u>via</u> a fistula. The design of the experiment (Hodgson, 1971d) was based on the premise that if the development of the intake of solid food was limited initially by eating behaviour, the response in voluntary food consumption to artificial changes in the quantity of digesta would be expected to be low immediately after weaning and to increase to a level characteristic of the mature ruminants some weeks later. The results demonstrated that the calves were unable to compensate fully for induced changes in the quantity of digesta in the rumen, in either a positive or negative sense immediately after weaning, however the responses reached adult level four to six weeks later (weaning was at five weeks of age).

From these results Hodgson concluded that the intake of solid food shortly after weaning was limited primarily by oropharyngeal factors. Furthermore the results suggested that the development of the alimentary tract was dependent on the development of the intake of solid food and not the reverse.

These results of Hodgson (1971d) are by no means conclusive as there was a large variation associated with the response of intake to the induced changes in the quantity of digesta in the rumen. However, there is some indirect data that may lend support to this proposal. The previously noted greater ability of the young ruminant, with increasing age, to equalize intakes of digestible energy from diets differing in energy concentration, could equally be argued to reflect the prominence of the oropharyngeal based mechanisms in controlling the intake of solid food in young ruminants. As the young ruminant becomes more adapted to a solid food (adaptation defined as the development of efficient mechanisms for prehension, mastication and swallowing of food) it is better able to cope with those diets, such as an unground roughage diet, which cause the young ruminant to spend more time eating and ruminating per unit DM intake than does a ground roughage or a concentrate diet. Further the response to the addition of sweetening agents to the rations appears to be greater in the young ruminant (Preston, 1956; Atai and Harschbarger, 1965; Gardner, 1967) than in older ruminants (Kare, 1959; Balch and Campling, 1962); a result which would be expected if behavioural factors are of greater importance in the control of food intake in young ruminants. Also recent evidence (Kellaway, Grant and Chudleigh, 1973b) has shown that exhaustion of the salivary glands to be an important factor in influencing the intake in early-weaned ruminants; a point which will be discussed in the next section.

Therefore although not conclusive, these results question the importance of rumen size as a controlling factor in the development of the intake of solid food shortly after weaning. However it would appear that the importance of the oropharyngeal based mechanisms as factors limiting food intake in young ruminants are transient, as their importance in in mature ruminants has been discounted (Balch and Campling, 1962) and also as has been previously mentioned, Hodgson (1971d) obtained "adult" responses to the induced changes in the quantity of digesta in the rumen when the calves were ten to twelve weeks of age.

The results of Hodgson's work were based solely on the use of dried grass as the solid food. Although this was of a moderate to high quality (<u>in vivo</u> DM digestibility ranged from 51.2 to 72.2%) the resulting live-weight gains of the calves were in the order of only 0.3kg/day. It may be possible that with concentrate diets of higher DE concentration, energy demands of the animal may be satisfied within the limits imposed by rumen capacity or oropharyngeal factors. The question of whether this is happening when concentrate diets are fed to early-weaned ruminants is discussed in the next section.

1.1.2. Diets, the Intake of which is possibly Controlled by Metabolic Means

As was mentioned in section 1.1.1., various workers have shown that when diets of varying energy are fed to young ruminants, the relationship between intake and the nutritive value of the diet is similar to the relationship decribed by Montgomery and Baumgardt (1965a) for older ruminants (see Fig. 1.1.). From the results, these workers concluded that the intake by young ruminants receiving a diet of high DE concentration was controlled by the physiological demand of the animal. However the validity of this conclusion can be questioned on two points.

(i) When an animal's intake is being controlled by its demand for energy, then theoretically that animal should be performing near its genetic potential.

In the experiments (Kay et al., 1970, 1972; Kang and Leibholz, 1973) where calves were weaned at five weeks of age and fed diets of varying energy concentrations, the maximum growth rate of the calves was in the order of 0.8kg/day. However, Friesian calves fed a liquid diet over the corresponding period of age had growth rates of 1.2kg/day (Roy, 1964) well above those for the calves weaned early. This would suggest that factors other than the physiological demand for energy was controlling the intake of these concentrate diets by the early-weaned calf.

It is more difficult to establish whether or not the maximum growth rates of lambs weaned early onto concentrate diets of varying energy content corresponds to their potential growth rate.

This is because no data could be found in the literature giving the growth rates of lambs receiving a liquid diet *ad libitum* over the corresponding period of age to those weaned early. However, for reference the maximum growth rates of the lambs weaned early corresponds to the maximum growth rate given by Large (1965) for lambs reared naturally on their mothers at pasture; namely 0.3 - 0.4 kg/day. Therefore unlike the work with calves the work with lambs cannot be validly criticized on this point, although this doesn't necessarily mean that criticism in this regard is not warranted.

(ii) In the experiments the results of a similar growth rate of the animals receiving a range of diets varying in energy (fibre) content was taken as confirmation that the animals were eating to maintain a prescribed energy intake. This is a dubious basis on which to draw conclusions, especially in view of the work of Jahn, Chandler and Polan (1970) and Strozinsky and Chandler (1971) who concluded that when rations of varying fibre levels are evaluated on the basis of live-weight gain only, results can easily be misinterpreted because of differences in amounts of digestive tract fill. They noted a positive linear relationship between fill and the level of the fibre in the ration. This could explain why in the work of Owen *et al.*, (1969b) that despite a decrease in the digestible DM intake with increase in the fibre level of the ration, the live-weight gains of the lambs remained constant.

These two criticisms do not unequivocally disprove the existence of a homeostatic mechanism operating to maintain a prescribed intake of energy by young ruminants, but they do raise doubts. In an attempt to substantiate these doubts an alternative explanation as to why this relationship between nutritive value and intake occurs in early-weaned ruminants is given below.

The levelling off, or even in one case (Kay et al., 1970) the falling off of DE intake of the early-weaned ruminants with further increases in the DE concentration of the diet may have been related to a concomitant decrease in rumen pH with these types of diets (cf. Bhattacharya and Warner, 1967). It is well known that when high grain diets are fed to ruminants the condition of lactic acidosis can result (Kellaway et al., 1973b). This impairs rumen motility which can lead to bloat and is generally associated with anorexia (Scarisbrick, 1954). Also Kay, Fell and Boyne (1969) have shown that pathological changes take place in the rumen wall when the pH of the rumen contents fall below 5.6. These are characterised by lesions of hyperkeratosis, papillary clumping and a thickening of the epithelium and lamina propria. It is likely that this condition of rumenitis is occuring in early-weaned lambs and calves fed a concentrate diet to appetite, as Andrews et al., (1969) and Kay (1969) have shown under these conditions the rumen pH is below pH 5.5. There is also recent evidence that the decrease in rumen pH does not have to be gross to effect a decrease in intake. Bhattacharya and Warner (1967) working with steers showed a significant drop in the intake of hay by these animals when they decreased the rumen pH by approximately one pH unit from the 'normal' rumen pH of 7. It is not clear how this small change in pH had its affect on intake or even if it was a direct one (see review Jones, 1972), but the fact that pH or related factors are monitored by the animal and in turn influence intake, may be of particular importance with regard to the control of diets of high DE concentration especially when fed to early-weaned ruminants (the meaning of this is discussed below).

One of the main reasons for the decrease in rumen pH associated with the diets of increasing energy concentration is that the buffering potential of the salivary secretions, which is a chief source of buffers for the rumen, is decreased under these conditions. This decrease is a reflection of a lowering of both total salivary secretion, and buffering capacity of the saliva brought about by the animals receiving concentrate diets having low times of rumination (Oltjen, Putman and Davis, 1965).

Restoration of rumen pH to more normal levels and thus increases in intake when diets of high DE concentration are fed, can be brought about by the inclusion of some fibre in the diet (Preston, 1963). Fibre has this effect in two ways; firstly, as a supply of basic cations (Matrone, Ramsey and Wise, 1959) and secondly, by stimulating salivary secretions (Weiss, 1953 cited by Preston 1963), which are several times greater during the process of eating and ruminating than when the animal is at rest (Stewart and Dougherty, 1958; Bailey and Balch, 1960). Kellaway _et al._, (1973a) demonstrated that the latter function of the roughage in this regard was the more important of the two.

To overcome the problems of rumen disorder associated with the feeding of diets of high DE concentration, it is generally recommended to include in the diet approximately 10% roughage (Warner and Flatt, 1965). However, recent findings by Kellaway _et al._,(1973b) raise doubts as to whether the inclusion of roughage alone is sufficient to restore the rumen pH in early-weaned ruminants to high enough levels so that their intakes are not restricted by a low rumen pH. Evidence for this came when they obtained a positive relationship between the DM intake of concentration and the levels of buffers included in this diet even when the calves were eating up to 10% of the DM intake as straw chaff. They concluded that this additive effect of roughage and buffers on food intake and calf growth rate suggested that the intake of roughage was insufficient to stimulate the production of sufficient saliva to prevent hyperacidity and a reduction in the total intake of food. This supports an earlier conclusion reached by Kay (1966) that the production rate of saliva in young ruminants is much lower in relation to gland size than in adult ruminants, and even when fully stimulated total production of saliva may be such that buffers are deficient in supply. There was no clinical symptoms of acidosis in the calves of Kellaway et al's.(1973b) experiment, but as was pointed out by the work of Bhattacharya and Warner (1967) the changes in rumen pH do not have to be gross to effect a decrease in the intake of food. Further the growth rates of the calves receiving the most favourable diet i.e. straw + highest buffered concentrate diet, (Kellaway et al., 1973b) were 1.02kg/day over the period of age of 6 to 12 weeks. This is the highest growth rate for early-weaned calves over this period recorded in the literature, and may indicate that once the deficiency of the buffering capacity of the early-weaned ruminant is overcome, it may be capable of attaining growth rates near its genetic potential.

In conclusion it would appear that the levelling off of DE intake with an increase in the energy concentration of the diet may be explained in terms of a concomitant decrease in rumen pH associated with these diets. The inherently low buffering capacity of the early-weaned ruminant may explain why even when some roughage is included in the diet the growth rates, especially of the calves, did not reach their potential for that particular period of age.

The overall conclusion from section 1.1.1. and 1.1.2. is that the intake of solid food by early-weaned ruminants may be controlled to a large extent by oropharyngeal based mechanisms and that young ruminants need time to become adapted to the solid food.

1.2. FACTORS INFLUENCING THE DEVELOPMENT OF SOLID FOOD INTAKE IN YOUNG RUMINANTS

In this section the effect of various factors i.e. birth weight, sex of animal, milk feeding regime and characteristics of the solid food, on the development of the intake of solid food in young ruminants will be discussed.

1.2.1. Birth Weight

Within any one breed there is a considerable variation in the weight of calves born, and it has long been the belief of practical husbandmen that the growth of lighter calves is not as good and their mortality rate higher than heavier ones. This contention has recently been criticized by Kay (1969) who examined records of 150 Friesian bull calves, birth weights of which ranged between 33 and 48kg, and found no effect of birth weight on the growth of these calves from weaning to 100kg live weight. Assuming that comparable growth rates implies comparable intakes, similar results have also been reported by Lawrence and Pearce (1965) and Davies and Owen (1967). Contradicting these results, Leaver and Yarrow (1972) demonstrated a positive relationship between birth weight and concentrate consumption by calves. In their experiment however, a constant milk allowance was fed over a range of live weights, resulting in the heavier calves being under-fed relative to the lighter ones; a situation which could give rise to this contradictory result (see section 1.2.3.)

In fact the poorer performance generally noted with lighter calves may arise in part from some of the general feeding recommendations used; for example feeding a milk allowance to calves based on a fixed percentage of the calf's live weight, under feeds the lighter calves relative to the heavier ones (Roy, Shillam, Hawkins and Lang, 1958).

In conclusion it is doubtful whether within a breed birth weight of the calves has any influence on their subsequent performance, as long as allowance is made for it in the feeding recommendation. Whether this conclusion is applicable when the difference in birth weight is due to a breed effect has not been adequately tested, although results of Roy, Stobo, Gaston, Ganderton and Shotton, (1971) would suggest that it is.

1.2.2. Sex of Animal

Comparisions between intact male and female lambs (Morgan and Owen, 1973; Davies and Owen, 1967) and calves (Armstrong, 1966) suggest that sex has no effect initially on the development of the intake of solid food. Morgan and Owen (1973) further demonstrated that only after lambs had reached 25kg live weight (100 days of age) did a difference in favour of the male lambs become evident.

1.2.3. Milk Feeding Regime

The effect of the milk feeding regime on the development of the intake of solid food in young ruminants is discussed in three sections.

(i) The direct effect of the level of milk fed

(ii) The age of the animal at weaning

(iii) The carry over effect of the pre-weaning treatment on the intake of solid food post-weaning.

1.2.3.1. The direct effect of the level of milk fed–
An inverse relationship between the level of milk fed and the intake of solid food in young ruminants has been demonstrated by many workers (Mathieu and Wegat-Litre, 1961; Burt and Bell, 1962; Armstrong, 1966; Tayler, 1966; Hodgson, 1971e; Leaver and Yarrow, 1972 for calves and Spedding, Brown and Large, 1963; Davies and Owen, 1967 for lambs).
It was suggested by Preston (1963) that the level of milk fed was the main factor influencing the early development of the intake of solid food in calves and Hodgson (1971e) has demonstrated that this was a reflection of the calves' attempt to equalize energy intake.

An attempt has been made by Spedding et al.(1963) and Hodgson (1971e) to quantify the above mentioned inverse relationship. These two groups of workers feeding respectively lambs a solid food of fresh pasture and calves a solid food of dried grass, regressed the intake of solid food (Y, gDM/kgLW) on the allowance of milk substitute (X, gDM/kgLW).
The regression coefficients which are an indication of the ability of the calf or lamb to substitute solid food for a given change in milk intake, were significant in both cases and were also shown to increase with age. This latter point is particularly relevant with regard to age at weaning and this is discussed in section 1.2.3.2. This increase with age in the increment of the intake of solid food before weaning per unit decline in the allowance of milk may be due in part to the cumulative effect of low levels of milk feeding on the intake of solid food (Mathieu and Wegat-Litre, 1961). However, because the increase of the regression coefficient with age in the work of Spedding et al.(1963) was obtained even

when lambs were switched between different levels of milk feeding at frequent intervals, led Hodgson (1971e) to propose that this response to the intake of solid food with age was probably related to the animal becoming increasingly adapted to a diet of solid food (see section 1.1.). It may also be that as a young ruminant ages it has a greater propensity to eat solid food, as Preston (1963) stated that it is axiomatic that the very young calf prefers milk to any solid diet. Obviously the value of the regression coefficient is going to alter with the type of solid diet, as the young ruminant becomes more easily adapted to some diets (pelleted concentrates) than to others (long roughage) cf. Hodgson (1971a).

This increase with age of the regression coefficients would suggest that an advantage in performance would be gained if a given quantity of milk was distributed such that lambs and calves received a higher level when they were younger and thus had a lower substitution rate of solid food for milk. However, the limited work with lambs and calves (Preston, 1956; Quayle, 1958; Clark and Whiting, 1961; Owen et al.,1969a) would not support this suggestion as these workers showed that the pattern of the distribution of a given quantity of milk over a fixed time period had little effect on the performance of the lambs and calves.

In conclusion it appears that the performance of milk-fed ruminants is insensitive to the distribution of milk feeding, but is sensitive to the level of milk fed. However, the level of milk feeding in the pre-weaning period has a residual effect in the post-weaning period and so to keep a perspective, the level of milk feeding pre-weaning must be interpreted in respect of its effects post-weaning. This is discussed in section 1.2.3.3.

1.2.3.2. The age of the animal at weaning - That a check in the live-weight gains at weaning is related to the age of the animal has been demonstrated in calves by Converse (1949), Hodgson (1965) and Stobo, Roy and Gaston (1967a) and in lambs by Brown (1964) and Ørskov, Fraser and Gill (1973). The work of Hodgson (1965) and Stobo *et al.*(1967a) showed that this was the result of a slower rate of increase in the intake of solid food post-weaning with the younger animals, reflecting the lower extent of the substitution of solid food for milk at this younger age. Part of this effect may be due to age *per se*, although age at weaning is often a reflection of a number of other variables which may or may not be related to the development of the intake of solid food post-weaning.

1.2.3.3. The carry over effect of the pre-weaning treatment on the intake of solid food post-weaning - It has frequently been emphasized that if calves are to be weaned at an early age they should be encouraged to eat as much solid food as possible before weaning (cf. Preston, 1957). However, there is some confusion in the literature in regard to the quantitative importance of the intake of solid food pre-weaning as it affects the intake of solid food post-weaning. The confusion can be reconciled to some extent by considering the relationship between the intake of solid food before and after weaning in two catergories:

(i) When comparisons are made between individual animals reared on the same treatment - this is where the confusion arises as workers have produced contradictory results. Quayle (1958) cited by Hodgson (1965) showed that the relationship between the intake of solid food by calves before and after weaning was not close. This result was supported in part by Davies and Owen (1967) when a group of lambs in their experiment received a restricted supply of milk. However, when a further group of lambs in this same experiment were fed an ad libitum supply of milk a close relationship between the intake of solid food before and after weaning resulted. This contradiction is not simply related to the amount of milk fed, as Lawrence and Pearce (1965) when feeding calves a restricted milk ration obtained a highly significant relationship between the intake of concentrates before and after weaning. Thus results describing the relationship between the intake of solid food before and after weaning are inconsistent when comparisons are made between individual animals reared on the same milk treatment.

(ii) When comparisons are made between different groups of animals receiving different levels of milk and weaned at the same age - the confusion that was present in the previous section does not arise here, as workers (Hussian, 1963 cited by Hodgson, 1971; Davies and Owen, 1967; Hodgson, 1971) have consistently shown that with groups of animals receiving different quantities of milk and weaned at the same age, the resulting difference established in the intake of solid food before weaning tended to persist for some time post-weaning. The reasons why this difference in the intake of solid food should persist are not clear, as although one may expect part of the reason to be due to a greater development of the rumen in calves eating more solid food, Hodgson (1971cd) demonstrated that rumen development was dependent on the intake of solid food and not the reverse.

Another possibility is that calves through receiving more solid food before weaning are better adapted to it and so can increase the intake of solid food after weaning at a more rapid rate. In this regard Hodgson (1971a) demonstrated that whereas after weaning the intake by calves of dried grass fed in the loose long form was dependent to a significant extent on the calves pre-weaning experience of it, this was not the case when the same dried grass was fed in the ground pelleted form.

Regardless of why this phenomenon occurs, the general relationship between the intake of solid food before and after weaning has important practical significance. In order to obtain a high intake of solid food after weaning, one has to forego performance pre-weaning because of the necessity of restricting milk to encourage the intake of solid food. More work is needed in this area to determine the appropriate balance between these two opposing factors, as the limited work to date has produced contradictory results. This is illustrated by the work of Aitken, Preston, Whitelaw MacDearmid and Charleson (1963) and Owen et al. (1969a) who showed that any advantage gained in live weight pre-weaning with the higher milk-fed groups, was lost in the subsequent post-weaning period; a result which was contradicted by Hodgson (1971e) and Morgan and Owen (1972, 1973) who showed that the advantage gained in the pre-weaning period with the higher levels of milk fed persisted despite a lower level of intake of solid food with these animals post-weaning.

1.2.4. Dietary Factors of the Solid Food

To exploit a calf and lamb rearing system which uses a low level of milk feeding as does that developed by Preston (1957) and Khouri (1969), it is necessary to use a solid food which promotes a rapid increase in intake under the given milk feeding regime.

As the young ruminant has a smaller rumen capacity and/or limitations in its eating behaviour, the diet must be of high density and high DE concentration. Whether to present this diet in the form of a meal or pellets depends on the quality of the diet in question. Owen et al.(1969b) and Kay et al.(1972) demonstrated that lambs and calves were better able to compensate for energy dilution of the diet by coarse roughage (oat husks and chopped straw respectively) when the diet was pelleted. The advantages of pellets as opposed to meal is less apparent at low levels of roughage inclusion. Lassiter (1955) found that calves having free access to both pellets and meal, selected pellets in preference to meal, but when each was singly and seperately fed there was no significant difference in intake. This latter result was supported by Hardy (1972).

The other major limitation of young ruminants that has to be allowed for, is the immature buffering system. This can be overcome to a certain extent by adding buffers to the foods However for the long term benefit of the young ruminant some roughage is needed, as Wilson (1963) concluded that the parotids grew and matured in response to mechanical stimuli provided by the food. In this respect ground roughage is of little use and to be effective roughage must be in the long form; a situation which is in opposition to the first limitation mentioned. However, the level of roughage inclusion can be reduced if care is taken in the method of processing the grain component of the concentrate ration. Furthermore, Kay (1969) cited experiments at Rowett which clearly showed that when care was taken during the processing of the diet to retain the husk on the cereal grains, calves did not suffer from bloat and they converted their food into body-mass more efficiently than did calves offered the same diet in the loose form. Moreover it was demonstrated that whole pelleted cereals were superior to ground pelleted cereals as a food for early-weaned calves.

It was mentioned in section 1.1. that because of the postulated prominence of oropharyngeal factors in controlling the intake of solid food in young ruminants shortly after weaning, palatability of the solid food is important. This agrees with the comment of Preston (1963) that the palatability of the solid food diet was of major importance in the development of its intake by the calf. Also the fact that calves are very selective grazers (Hodgson, 1968) would indicate that palatability has an influence on intake. However, palatability is difficult to define exactly, since it is a concept rather than a scientific term (Marten, 1969, cited by Greenhalgh and Reid, 1971) and there is confusion as to whether it is important in influencing intake in adult ruminants. Balch and Campling (1962) claim that it is unimportant in influencing the level of intake of a diet fed singly (a contention recently challenged by Baile and Mayer, 1967; Greenhalgh and Reid, 1971), but did consider it important in the intitiation of eating.

This latter point is particularly relevant in the context of inducing young ruminants to eat solid food. However, because of the problem in defining palatability, it is difficult to know what factors are important in causing a palatability response. The one normally chosen is taste. In this respect a number of workers (Preston, 1956; Atai and Harschbarger, 1965; Gardner, 1967) have demonstrated positive responses in DM intake when sweetening agents were included in the diets, indicating perhaps a palatability response.

Texture is another palatability factor and Ray and Drake (1959) claimed that coarse textured concentrates are more palatable than fine textured ones. However, texture in this context is probably confounded by the promotion of more favourable rumen conditions by the coarse textured diet. Palatability does not appear to be important in influencing the choice of cereal for a concentrate ration, as Kay (1969) cited unpublished work of Kay and Macleod showing that either wheat, barley or maize could be used interchangeably in the ration without affecting intake or production. This supports a conclusion of Caffrey and McAleese (1965) that the differences in palatability between cereals for calves are usually confounded by the preparation of the cereals.

In conclusion, the type of food that is most suitable for weaning calves and lambs on to, is one which is "palatable", has a high energy density and promotes and overcomes the immaturity of the buffering capacity in the rumen of the young ruminant.

1.3. PASTURE AS AN EARLY-WEANING FOOD FOR CALVES

This will be discussed in two sections:

(i) a deductive appraisal of pasture as an early-weaning food for calves will be made with inferences being deduced from information given in section 1.1.

(ii) work, where pasture has been the major or sole food fed to young ruminants will be cited to give a quantitative appraisal of pasture as an early-weaning food for calves.

1.3.1. A Deductive Appraisal of Pasture as an Early-weaning Food for Calves

The type of pasture which is normally made available to the young calf is characterised as being short and leafy. Such a pasture, although having a metabolizability in the range of 2.7 - 3.0 Mcal ME/kg DM, when fed fresh has an energy density of approximately 0.41 Mcal ME/kg wet matter (WM), as the average DM content of this type of pasture is 15%. Further this pasture would have a crude protein content of about 19%, while the crude fibre content would be of the order of 21% (Corbett, 1969).

Calves from as young as three weeks of age have the ability to digest pasture with an efficiency comparable to mature animals (McArthur, 1957; Preston, Archibald and Tinkler, 1957). Also the high values for the crude protein levels of this pasture would suggest that it is adequate to supply the protein requirements of early-weaned calves, as Stobo *et al.* (1967 b) found that 16% crude protein of a diet fed to calves supplied the requirements of protein for maximum weight gain.

It would therefore appear that the qualitative characteristics of pasture are sufficient to consider it as an early-weaning food for calves. However the question arises whether the calves have the ability to take in a sufficient quantity of pasture to allow for satisfactory rearing.

The low energy density of pasture coupled with a moderate fibre content would suggest that calves must spend a long time grazing and ruminating per unit DM intake of pasture. To give an indication of this, the results of a number of studies, where the grazing behaviour of calves at pasture has been observed, are summarized in Table 1.1.

TABLE 1.1. Time spent grazing and ruminating during a 24h period by calves at pasture

Age of calf (weeks)	Other foods fed	Time spent grazing (h)	Time spent ruminating (h)	References
7	1gal. whole milk	5 - 6.5	7	Stewart(1961)
7	116/10 lb live weight up to max. 11 lb	5.6	6.8	Roy *et al.* (1955)
6 - 7	weaned at 3 weeks	7.3	*	Godfrey(1961)
9	1.5gal. milk sub/day	5.6	5.7	Chambers(1959)

* Not available

There was no intake data associated with these studies but the results do indicate that the calves must spend a long time eating and ruminating when they are receiving pasture as the major dietary constituent.

In view of the postulated importance of oropharyngeal factors in controlling the intake of the young ruminant shortly after weaning (see section 1.1.) the low energy concentration and the moderate level of fibre of fresh pasture causing calves to spend a long time eating and ruminating is a serious disadvantage of pasture.

The long rumination times of the calves grazing pasture (see Table 1.1.) is indicative of the slow rate of breakdown within the calf's rumen of the ingested pasture into particle sizes suitable for passage out of the rumen and down the hind gut. This is the result of the pastures moderate level of fibre, coupled with it being fed in the long form. This would suggest that the pasture would take up a considerable volume within the rumen and that the calf's intake of pasture may be limited by rumen capacity. In this regard Hodgson (1968) studied the intake of pasture by calves aged between three and six months and found that there was a linear relationship between organic matter (OM) intake and OM digestibility over the OM digestibility range of 68 to 80%. He concluded that in these young animals the intake of pasture even at very high digestibilities was governed predominately by rumen fill.

A further complication with pasture is that when it is fed fresh it has a high moisture content. It is unlikely however, that this high moisture content per se is important in influencing the intake of pasture by calves compared to the affect of the actual physical form. This is demonstrated to a limited extent by a comparison of two similar experiments, where calves were weaned at six weeks of age off milk substitute fed ad libitum onto either fresh pasture (Longsdale and Tayler, 1969) or dried pasture fed in the long form (Longsdale and Tayler, 1971). Both diets were of similar quality and both promoted similar live-weight gains of the calves. Although there are other variables associated with the removal of moisture from pasture, the comparison of these two experiments would suggest that the removal of the moisture did not improve the calves' intakes of it.

In conclusion, the major limitations of pasture as an early-weaning food for calves would seem to lie with its physical characteristics, the major one of which is that it is in the long form. The effect of this form of diet presentation is exaggerated by the moderate levels of fibre which would slow the break-down of pasture within the rumen into particle sizes conducive to passage through the hind gut. This combination of factors leads to the probable control of the voluntary intake of pasture by calves shortly after weaning, by a combination of oropharyngeal and rumen fill based mechanisms. As a concentrate diet through its greater DE density and smaller particle size largely over comes the limitations placed on intake by these two mechanisms, it is probable that shortly after weaning calves would have a greater intake of a concentrate diet compared with pasture.

1.3.2. Quantitative Appraisal of Pasture as an Early-Weaning Food for Ruminants.

The work of Chambers and Alder at Hurley (Chambers, 1961ab; Chambers and Alder, 1960, 1961) demonstrated that Autumn and Spring pasture (DM digestibility 63 to 75%) was comparable to concentrate-with-hay as a food for pre-weaned calves.

However, as the level of concentrate intake was limited to one third of the total DM intake, with hay making up the balance, the comparison does not reflect the true relative merit of pasture compared with concentrates. Spedding, Large and Brown (1961), Brown (1964) and Large and Spedding (1964) found that weaning of lambs at three weeks of age onto pasture was not successful unless concentrates were fed. Further Gleeson (1971) demonstrated a decrease in performance when calves six weeks of age were changed from a diet of concentrates to pasture. He also showed that over the period of six to fifteen weeks of age, calves receiving a concentrate diet grew faster than those receiving pasture, i.e. 0.68 kg/day compared with 0.37 kg/day. However, this growth rate for those calves receiving pasture was lower than that demonstrated by Longsdale and Tayler (1969) who obtained growth rates of 0.54 and 0.46 kg/day when calves were weaned at around six weeks of age onto pasture, after receiving milk substitute ad libitum for four and 4.5 weeks respectively.

In conclusion it would appear that pasture is inferior to concentrates as an early-weaning food for calves, although the growth rates which pasture can promote may be sufficient for dairy replacement stock, which over this period of life have a 'target' live weight gain between 0.45 and 0.55 kg/day (McMeekan, 1956; Crichton, Aitken and Boyne, 1959).

An experiment was therefore designed to test the following hypotheses:

(i) That pasture was inferior to concentrates as an early-weaning food for calves, with the calves being able to take in more concentrates than pasture despite similarities between the two foods on a qualitative basis i.e. digestibility.

(ii) As a number of workers have demonstrated a permanent affect of undernutrition in the young ruminant under the age of twelve weeks (e.g. Everitt, 1972; Reardon and Everitt, 1972) live weight measurements were continued after the experiment to test the hypothesis that a difference in live weight established in calves early in life is permanent i.e. no compensatory growth will occur.

CHAPTER TWO

MATERIALS AND METHODS

2.1. DESCRIPTION OF EXPERIMENT

The experiment was of a completely randomized design, where two groups of calves, seven in each group, were used to compare pasture with concentrates as an early-weaning food for calves. The two groups were classified as follows:

Group C - this group of calves was to receive concentrate as the early-weaning food.

Group P - this group of calves was to receive pasture as the early-weaning food.

The experiment was divided into two main periods, A and B, with period A further divided into three sub-periods, A1, A2 and A3. The classification of each of these periods is given in table 2.1., while the detailed feeding management of the calves over period A is given in table 2.2. The periods are defined in terms of the calves' age, with day 0 corresponding to day of birth.

TABLE 2.1. The experimental plan giving the classification of the periods which the experiment was divided into along with the change in the age of the calf over each period

Period A (0-84 days) Experimental period				Period B (85+ days)
Period A1 (0-28 days)	Weaning (29 - 35 days)	Period A2 (36-56 days)	Period A3 (57-84 days)	
Pre-weaning period		Comparison period	Post-comparison period	Post-experimental period

The objectives of each of these periods are discussed more fully below.

2.1.1. Objective of Period A1 (0-28 days of age)

The objective of this period was to prepare the calves for weaning by five weeks of age, with the constraint that the pre-weaning management would not bias the comparison of pasture with concentrates as an early-weaning food for calves. In an attempt to meet this constraint both groups over this pre-weaning period were treated similarly. There were two pre-requisites considered necessary to achieve the objective of preparing the calves for weaning early, when half of them would be weaned onto pasture.

(i) Ensure adequate levels of intake of solid food - To obtain this, the allowance of milk fed to the calves was restricted to a level which would support maintenance and approximately 200g daily live-weight gain. This level was chosen as Preston (1963) had commented that calves on this level could be induced to eat 500g of solid food daily, by three weeks of age.

(ii) Part of this intake of solid food must be pasture - It was considered necessary to give calves experience in eating pasture prior to weaning, as Hodgson (1971a) - see section 1.2.3.3. - had demonstrated that calves receiving this type of diet had significant improvements in their post-weaning intakes, if they had had experience of this type of diet prior to weaning. This requirement was achieved by restricting the level of the concentrate diet fed.

2.1.2. Objective of Period A2 (35-56 days of age)

The objective of this period was to compare pasture with concentrates as an early-weaning food for calves; this being the major objective of the experiment. To assist in the interpretation of the results, digestibility, rate of passage and eating behaviour studies were carried out. The digestibility study would demonstrate whether there was a qualitative difference between the two diets, while the latter two studies would aid in the interpretation of any difference that might occur in voluntary intake. The aim of feeding a small allowance of pasture to the calves of group C, was to accustom them to eating pasture in preparation for their change of diet from concentrate to pasture during period A3.

2.1.3. Objective of Period A3 (57-84 days of age)

This period was included to obtain some information on the ability of calves at this age, to substitute pasture for concentrates and to observe if there was any carry-over effect of the feeding of concentrates to calves during period A2, on the intake of pasture by these calves during period A3.

2.1.4. Objective of Period B (85+ days of age)

The objective here was to look at the affect of the two rearing methods on the subsequent performance of these calves. During this period all of the calves were grazed together in one group.

TABLE 2.2. Detailed description of the feeding management of the calves during period A (0-84 days of age)

Period	Group	Food	Days fed	Amount
A1 0 - 28 days	Both C and P	Colostrum	0 - 4	Left on dam
		Milk	4 - 28	Sufficient for maintenance + 0.2kg/day live-weight gain*
		Concentrate	8 - 28	Restricted 0.2, 0.3 and 0.4kg/day for the 2nd, 3rd and 4th week respectively
		Pasture	8 - 28	Ad libitum
Weaning 29 - 35 days	C and P	Milk	29 - 31	Reduced by a quarter each day with calves weaned off milk by day 32
	C	Concentrate	29 - 35	Ad libitum
		Pasture		Restricted 0.5kg DM/day
	P	Concentrate		Restricted 0.3kg/day
		Pasture		Ad libitum
A2 36 - 56 days	C	Concentrate	36 - 56	Ad libitum
		Pasture		Restricted 0.5kg DM/day
	P	Pasture		Ad libitum
A3 57 - 84 days	C	Concentrate	57 - 69	Restricted initially to 1.5kg/day and reduced every 4days by 0.5kg
		Pasture	57 - 84	Ad libitum
	P	Pasture		Ad libitum

* Calculated from data of Roy et al. (1958)

2.2. EXPERIMENTAL FOODS

2.2.1. Milk

This was collected each morning prior to commencement of feeding and was kept at 4°C between the morning and afternoon feeds. The herd producing the milk was predominantly Friesian, with a milk fat test for the months of May and June of 4.4% and 4.1.% respectively.

2.2.2. Concentrate Diet

The concentrate diet was based on that proposed by Khouri (1969). It consisted of the ingredients listed below, with the addition of 10% finely chopped hay. This was added to ensure the health of the calves receiving this concentrate diet.

Ingredients	Percent
Rolled barley	65
Meat meal (60% protein)	14
Linseed meal (36% protein)	15
Dry molasses	3.2
Salt	0.8
* TVL calf food vitamin supplement	2
	100

The concentrate diet was fed to the calves in the form of a meal.

* Tasman Vaccine Laboratories (TVL) calf food vitamin supplement 1kg of which contains 2.715g vitamin A, 0.325g vitamin D, 3.248g vitamin E, 12.947g ascorbic acid, 0.014g cobolt carbonate, 0.019g potassium iodate, 0.054g copper carbonate, 3.550g ferrous fumerate, 2.436g manganese sulphate, 0.063g calcite and magnesite, 3.132g zinc oxide, and 975.047g lactose.

2.2.3. Pasture

Three paddocks were used for the supply of the pasture; descriptions of which are given below. The pasture was harvested intitially using an Allen motor scythe (John Allen and Sons Ltd. Oxford), with this later being replaced by a sickle-bar mower mounted on a tractor. The pasture was cut once daily, usually during mid-afternoon, and stored overnight in large plastic bags at 4°C. At 0800h the next morning it was removed and mixed thoroughly prior to feeding.

2.2.3.1. Paddock Description -

(1) Paddock 30 - The type of pasture was predominantly ryegrass (variety unknown as no record of sowing date and seed mixture was available) and white clover. Just prior to the experiment (16-4-72) the pasture was topped and topdressed with 126kg/ha of urea. Time of the last phosphate application was 6-3-71 when 377kg/ha was applied.

(ii) Paddock 29 - This paddock was sown in Autumn 1966, with a seed mixture/ha of 3.7kg Manawa ryegrass, 1.8kg Ariki, 1.8kg Ruanui and 1.4kg Huia white clover. Time of last phosphate application was 6-3-71 when 377kg/ha was applied.

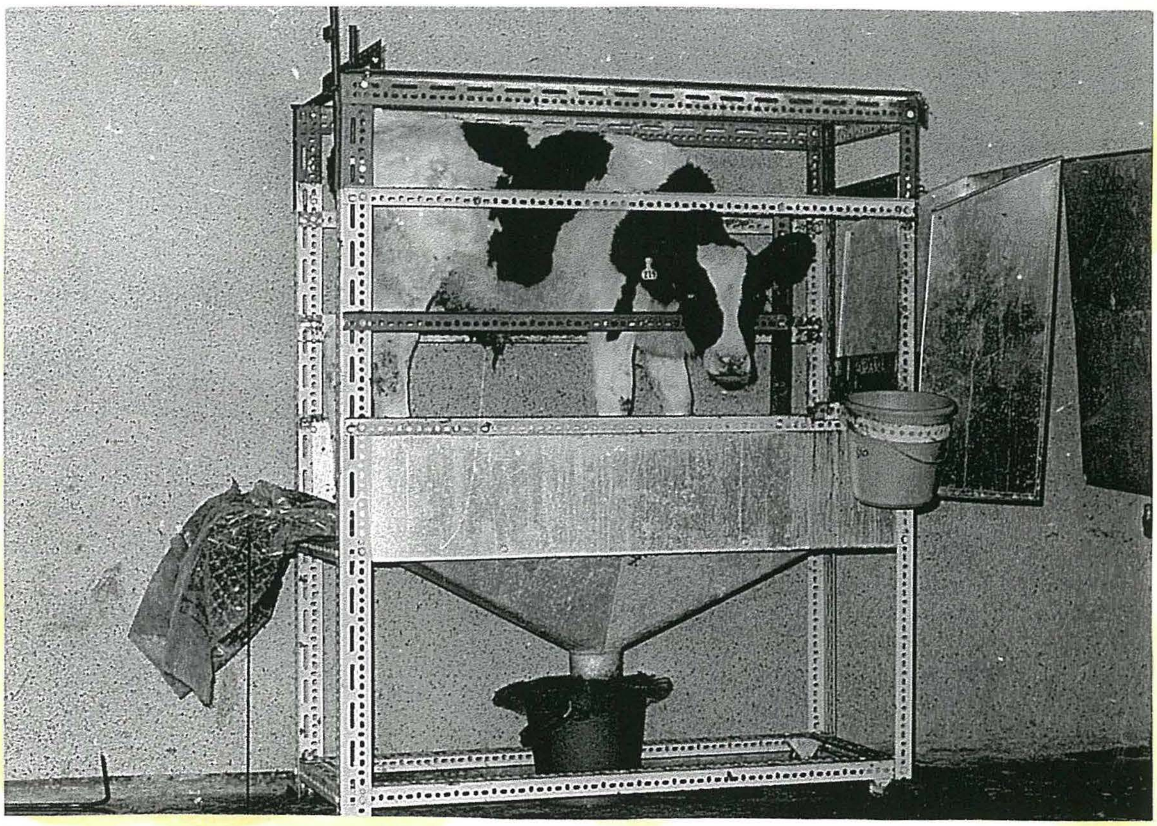
(iii) Paddock 10 - This paddock was sown in permanent pasture in Autumn 1972. The seed mixture/ha was Ariki 2.3kg, Manawa 3.2kg, Apanui Cocksfoot 1.8kg and Huia white clover 1.4kg. Urea was applied to the pasture at the rate of 250kg/ha on 12-5-72 and the last phosphate application (377kg/ha) was on 11-12-71, when choumoellier was the crop.

2.3. EXPERIMENTAL ANIMALS

Fourteen Friesian bull calves born during May 1972, were obtained from, either the Massey University No.1 dairy herd or purchased from local farmers. On arrival they were randomly allocated to their respective groups, fasted overnight (a procedure which is claimed to minimise the risk of infectious scours - Lawrence and Pearce, 1961) and weighed the next morning. The calf's fasted weight was used to calculate its daily allowance of milk.

Up until they were eight weeks old, the calves were kept in individual metabolism crates (see Plate 2.1.), while between eight and twelve weeks they were kept in individual pens and bedded down on straw (see Plate 2.2.). The calves' room was well ventilated and maintained at a constant temperature of 17°C. The relative humidity varied, but did not drop below 65%. The lights in the room were switched on in the morning and off at night, approximating the normal daylight pattern for that time of the year (May⟶August).

Any calves that showed signs of scouring were treated with sulphamezathine (sulphidimidine - I.C.I.) and given a drench of Kaluminox (National Dairy Association - Colloidial kaolin and aluminium gel, pectin and liquid paraffin). During period A, all calves irrespective of diet were drenched every two weeks with an anthelminthic barbendazole (Wormguard - Smith, Kline and French), while during period B the calves were drenched only at the times they were brought in for weighing.



tray extension aiding
faecal collection

Plate 2.1. Calf in Metabolism Crate (Periods A1 and A2)

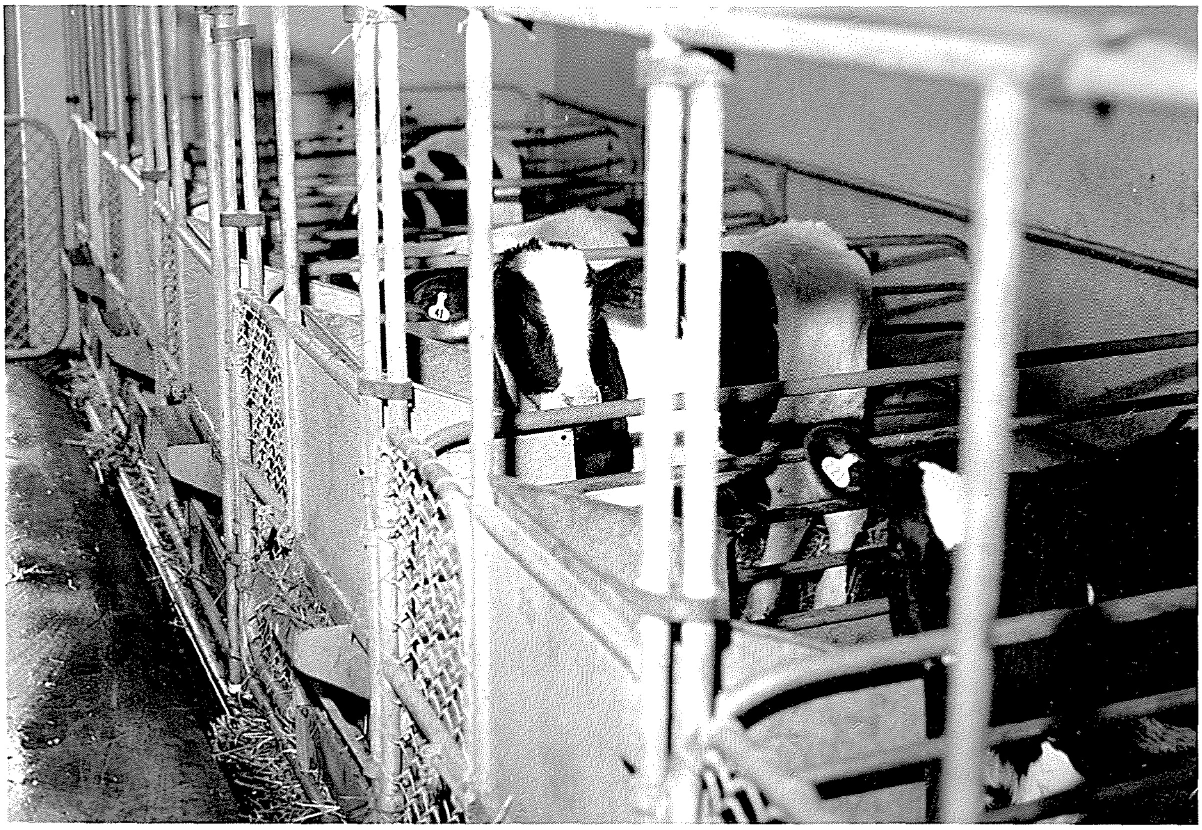


Plate 2.2. Calf Housing during Period A3

2.4. EXPERIMENTAL PROCEDURE

2.4.1. Chemical Analysis of the Diets

Both diets fed were sampled daily for DM determinations. For pasture, duplicate 200g samples were taken, while for the concentrate diet a single 50g sample was taken. The DM content of these samples was determined by drying them in a force-draught oven for nine hours at 90°C. As oven space over the period of the trial was at a premium and because it was found that the difference between the DM content of the samples determined over nine hours, compared with 24h was negligible, nine hour drying of the samples was adopted.

Whereas after drying, the daily sample of the concentrate diet was discarded, the daily sample of pasture was ground through a 1mm mesh in a Wiley mill and stored in air-tight plastic bags, to be later bulked on a paddock basis for chemical analysis. For the chemical analysis of the concentrate diet, samples of the concentrate and hay components making up this diet were obtained prior to the commencement of the experiment. Whereas the sample of the hay was finely ground through a 1mm mesh, the sample of the concentrate component was left in its intact form because of the difficulty encounted when trying to grind it. These two samples were stored seperately in air-tight glass jars.

The following chemical analyses were carried out:

Nitrogen – as by Macro-Kjeldahl	A.O.A.C(1965)
Ether extract	A.O.A.C(1965)
Ash	A.O.A.C(1965)
Gross energies – using adiabatic bomb calorimeter	A.O.A.C(1965)
Acid detergent fibre	Van Soest (1963)

2.4.2. Botanical Composition of the Pastures

The pastures of the three paddocks used in the experiment were assessed for their botanical compositions, i.e. the proportion of grass, clover and weed present. The botanical separations were carried out on samples of pasture which were obtained by the random sampling of each paddock. The separated fractions were dried and the composition expressed as a proportion by weight of the total.

2.4.3. Apparent Digestibility of the Diets

2.4.3.1. The DM digestibility of the pasture using sheep - The objective of monitoring the digestibility of the pasture using sheep, was as a control measure to see if any changes in the calf's digestibility of pasture was due to either, a change in the ability of the calf to digest pasture, or a change in the nutritive value of the pasture. This control procedure was carried out until the digestibility study with the calves had been completed.

Three harnessed mature sheep (two vasectomized rams and one rumen fistulated wether) were each fed a daily allowance of 0.8kg DM of the pasture, which corresponded to approximately a maintenance level of feeding.

Faeces were collected daily and bulked over a period of seven days. This resulted in a total of eight digestibility balance periods, each of seven days. At the end of each period of collection, the bulked wet faeces were weighed and two 200g samples were taken and oven-dried for48h at 90°C for determination of DM content.

2.4.3.2. <u>Digestibility of the diets using calves</u> – Ten calves, five from each group were involved in the digestibility trial. The organisation of this trial is given in Table 2.3.

TABLE 2.3. The organisation of the digestibility trial

	Balance period 1 (BP I)		Balance period II (BP II)			
Age period	15 – 28days		36 – 57days			
Organisation of faecal collection periods within each balance period	two periods of		four periods of			
	7 days	7 days	7 days	5 days	5 days	5 days

During BP II (which corresponds to period A2) the ability of the calf to digest pasturé compared with the concentrate diet was assessed.

The BP I was included to assess the affect of the age of the calf on the digestibility of the diets fed. To aid in this assessment, the two major balance periods were divided into a number of sub-balance periods, so allowing any affects of the age of the calf within the two major periods to be observed.

Faecal collection was achieved by allowing the voided faeces to pass through the grating into the receptacle of the metabolism crate, from where they were collected twice daily, mornings and afternoons. The faeces were bulked for each calf and stored at –10°C.

At the end of each collection period (for lengths of periods see Table 2.3.) the bulked wet faeces were weighed, thoroughly mixed and two samples of approximately 200g were taken and dried at 90°C for 48h, for determination of DM content. A further sample of 500g was taken, freeze-dried, then finely ground through a 1mm mesh in a Wiley mill and stored in air-tight jars.

While the DM content of the faeces was determined by oven-drying, the energy content was determined on the freeze-dried samples. The inconsistency of using the oven-dried DM and determining energy content on the freeze-dried samples, came about through an initial doubt that the freeze drier was not drying the samples sufficiently, as on average the DM content of the freeze-dried sample was 2% units higher than the corresponding oven-dried sample. As a check to see if this difference was due to moisture or loss of actual DM, energy determinations on some of the freeze-dried and the corresponding oven-dried sample were carried out. The results are given in Appendix I, with the conclusion that the difference was probably because of a difference in the moisture content.

2.4.4. Intake

The main feeding times were 0900h and 1300h and at each of these feeds the calves were fed half of their daily allowance of milk. The milk was warmed with the addition of hot water and fed to the calves from a bucket.

Initially the solid food was offered at the 0900h feed only, however, as the calves increased their intakes of it, the diets which were being fed *ad libitum* were offered at both feeding times. Also because the size of the food bins limited the amount of pasture which could be offered at any one time, pasture was replenished throughout the day as the food bins emptied. When a solid food was offered in a restricted amount, the daily allowance was given at the 0900h feed.

Except for an hour in the morning when food refusals were being collected, all calves had continuous access to their respective diets. To ensure ad libitum intakes, the concentrate and pasture was fed so that refusals were at least 10% of the day's intake. Food refusals were collected in the morning prior to feeding, weighed and sampled for dry matter determinations. For concentrate refusals a 50g sample was taken, while for pasture a 100g was taken. All of the calves had free access to water during period A. Daily water intakes were recorded during period A2 only.

The general objective of the feeding regime for period B was to make available a good supply of pasture at amounts in access of the calves' requirements, thus enabling any potential compensatory growth to be demonstrated. Over the summer pasture was in short supply, but both groups were treated alike throughout.

2.4.5. Live-weight Gain

During period A the calves were weighed weekly at 0800h, on scales accurate to ± 0.10kg. It was hoped that the recording of the live weight at exactly the same point in the feeding cycle would help minimize the error of gut fill.

For period B, the error of gut fill was minimized by fasting the calves without access to water for 15h. Weighing during this period was not on a regular basis.

Two methods were used to calculate the live-weight gains:

(1) By regressing live weight on age. This was used to calculate the live-weight gains of the calves over periods A1 and A2.

(2) By the difference method (Bailey, Broster and Burt, 1958) which is defined as:

$$\frac{\text{live weight at time } t_2 - \text{live weight at time } t_1}{t_2 - t_1}$$

This method was used to calculate the live-weight gains of the calves during period B and also the overall live-weight gains of the calves for period A.

2.4.6. Time of Retention of Undigested Residues of the Pasture and Concentrate diets fed during period A2

Four calves from each group, aged between six and eight weeks, were fed a proportion (4%) of their respective diet, pasture or concentrate, stained with safranine. The stained diet was fed at 2300h with the first faecal sample taken at 0930h and the subsequent fourteen samples spread over a period of seven days. The stained particles in these faecal samples were counted using Balch's (1950) method and the results were expressed as the mean time of retention (Castle, 1956).

2.4.7. Eating and Ruminating Behaviour

The daily eating and ruminating activities of three calves receiving pasture (group P) and two calves receiving concentrate (group C) were recorded over a continuous period of several days, during period A2. The apparatus used for the recording was based on that used by Campling and Freer (1966) although modified slightly by Davey (1973). The apparatus used is illustrated in Plate 2.3. while part of one of the recording charts illustrating the processes of eating, ruminating and resting, is given in Fig. 2.1.

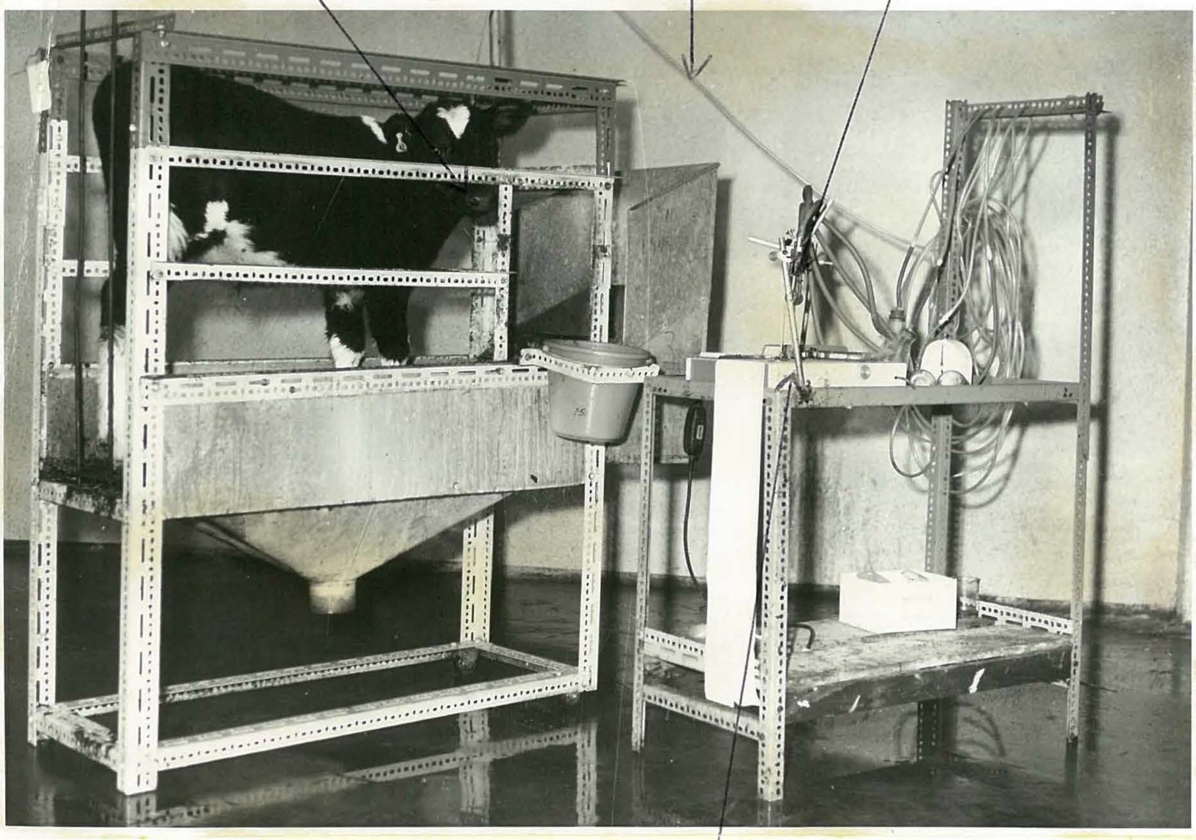


Plate 2.3. Eating Behaviour Recording Apparatus in Operation

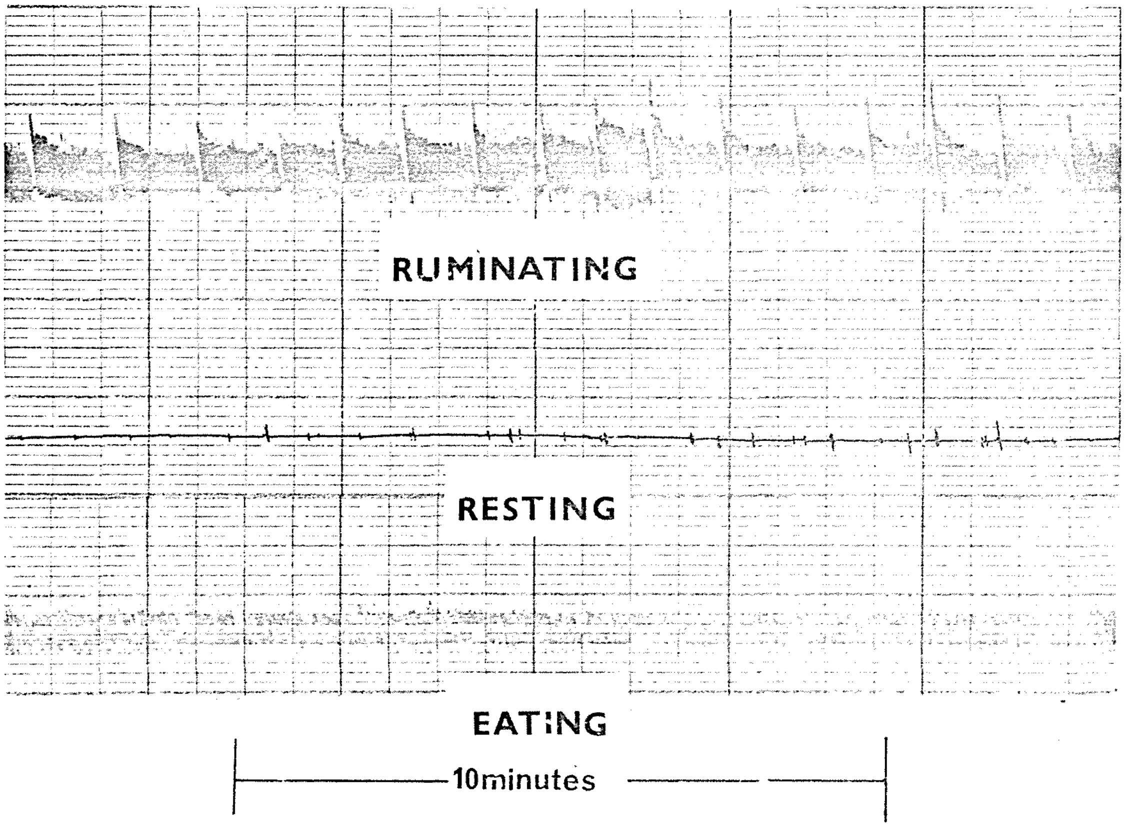


Fig. 2.1. Part of one of the recording charts illustrating the process of eating, ruminating and resting

2.5. STATISTICAL ANALYSIS

The treatment differences of the two independent groups were analysed according to the theory of the t - statistic. Where the variances of the two groups were shown to be heterogeneous, the data was analysed according to Snedecor and Cochran (1967) page 115. Where regression analyses were carried out, the population parameters were estimated by the least squares technique.

The Animal Production Journal's convention for showing the level of significance has been adopted. This is as follows:

a result which is	
non-significant	NS
significant at the 5% (0.05) level	*
significant at the 1% (0.01) level	**
significant at the 0.1% (0.001) level	***

CHAPTER THREE

RESULTS

3.1. ANIMAL HEALTH

The calves maintained remarkable health and vigour throughout period A, with the only ill affect apparent from their long sojourn in the metabolism crates being abrasions to their carpal (knee) and tarsal (hock) joints. These abrasions were treated frequently with iodine with the result that no infection became established.

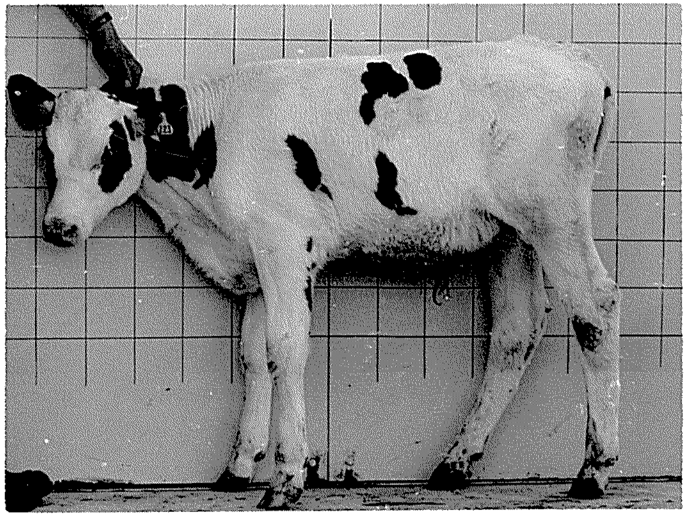
The incidence of scouring was low, with there being a total of only five calf-days when it occurred, and on each occasion treatment was successful, allowing the intake of milk to be maintained. Calf 11 developed a chronic navel infection that was repeatedly treated with procaine penicillin (A/S Rosco). During period A3 all animals were treated for lice with fenthion (Tiguvon-Bayer).

There appeared to be no ill affects caused by pasture being the sole food from five weeks of age. Only calf 12 developed a "pot-bellied" appearance, with this disappearing during period B. Photographs of a representative selection of the calves are shown in Plate 3.1.

Calf health was not maintained during period B. Within nine weeks of being put out to pasture three calves had died, two from bloat and one from the navel infection previously mentioned. During the summer period (January, 1973) the calves developed staggers and it was at this time that a further two calves died through mis-adventure.

Group C

Group P



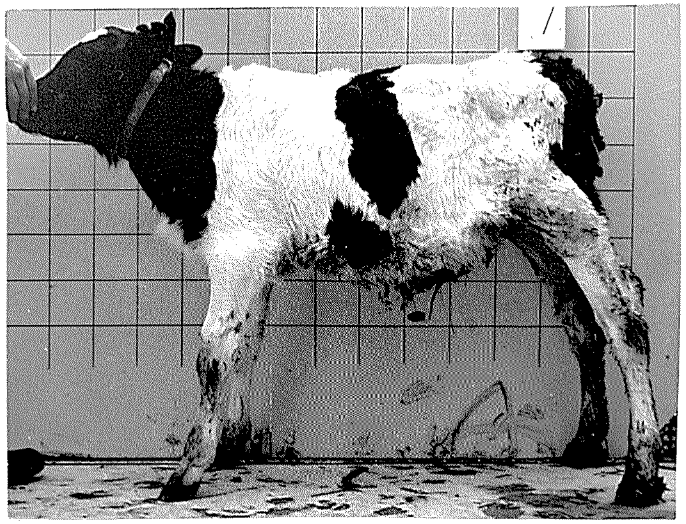


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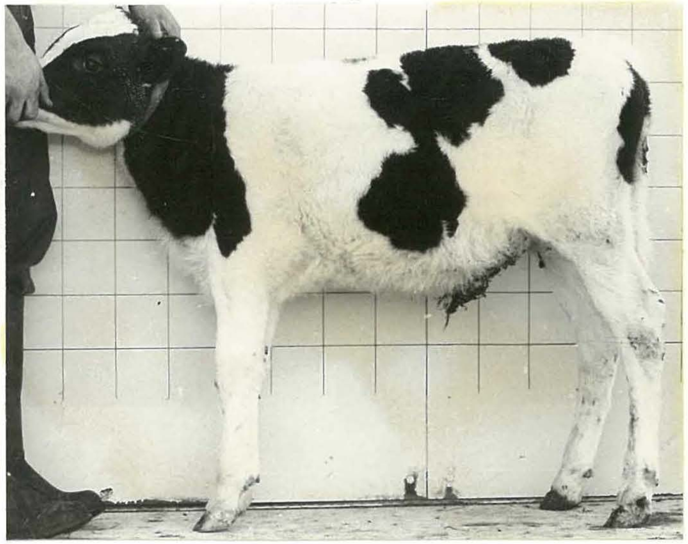
Plate 3.1. A Representative Selection of the Calves when Eight Weeks of Age

Group C



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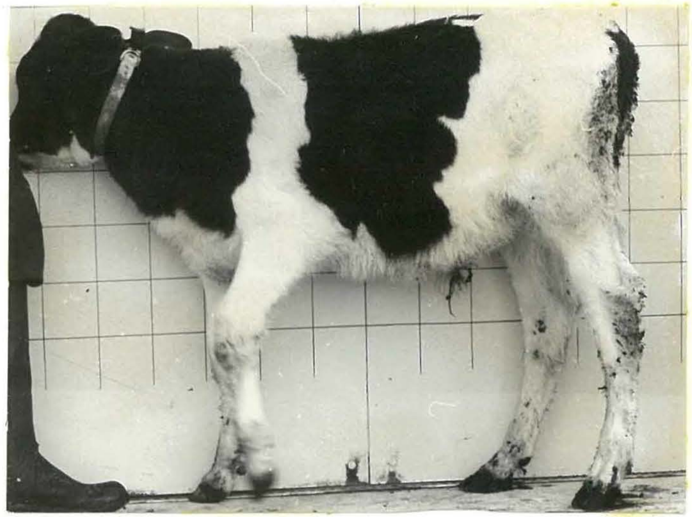
Group P



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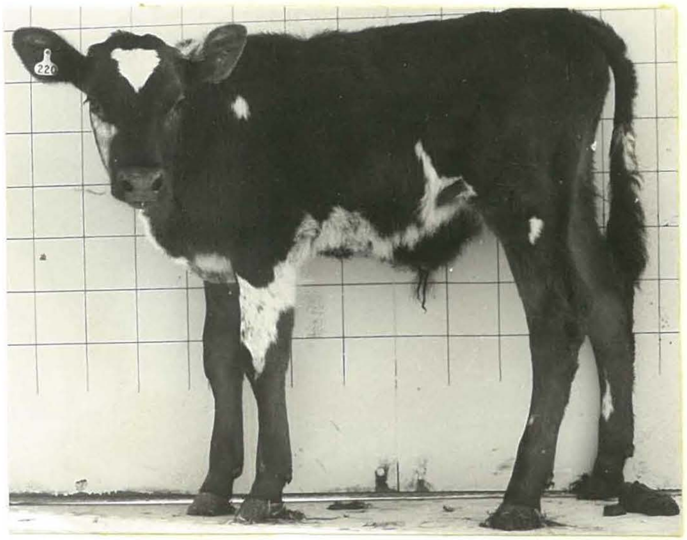

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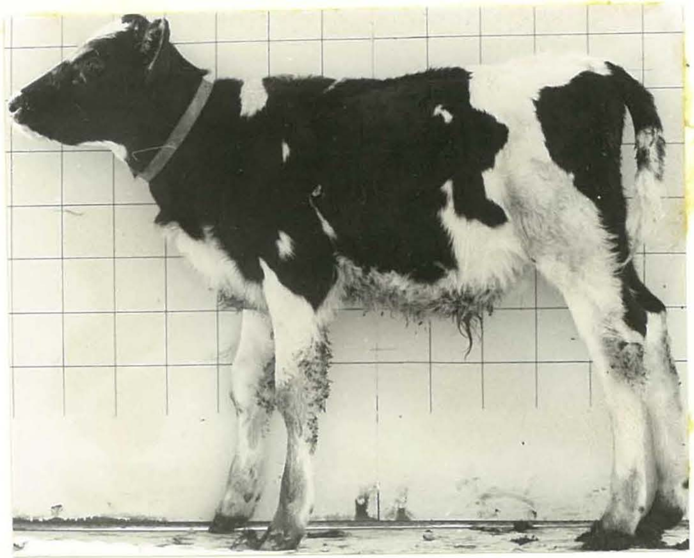

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Plate 3.1. contd...

With only nine animals left (five in group P and four in group C) period B was prematurely terminated.

3.2. FOOD ANALYSIS

3.2.1. Chemical Analysis

A summary of the chemical composition of the pasture and concentrate diets is given in Table 3.1. On the basis of this chemical analysis the pastures cut from the three paddocks were very similar. The lower DM content of the pasture from paddock 10 was a reflection of the short time this pasture had been sown (see section 2.2.3.1.). The values for the acid detergent fibre of the pasture confirms that it was in the vegetative state, however they also demonstrate that pasture contains considerably more lignin and cellulose (acid detergent fibre) compared with the concentrate diet.

3.2.2. Botanical Analysis

A summary of the botanical compositions of the pastures fed to the calves is given in Table 3.2.

TABLE 3.2. Botanical composition of pasture
(% DM)

		Grass	Clover	Weed
Paddock	30	60	34	6
	29	70	20	10
	10	77	-	23

Associated with paddock 29 was a large litter of dead leaves which had fallen during the Autumn from the number of

TABLE 3.1. Chemical composition and energy content of diets

Diet		DM (%)	% DM: Crude protein (Nx6.25)	% DM: Acid detergent fibre	% DM: Ether extract	% DM: Ash	GE content (kcal/gDM)
Concentrate		91.2	23.0	7.0	4.2	4.8	4.603
Hay		89.5	7.8	33.9	2.7	8.0	4.230
*Concentrate + 10% hay		91.0	21.5	9.7	4.0	5.1	4.506
Pasture	Paddock 30	13.9 - 22.1	22.1	20.6	7.3	10.3	4.646
	29	14.7 - 19.8	20.1	20.3	7.3	12.6	4.375
	10	11.3 - 13.4	24.9	19.9	7.5	11.4	4.409

* This was the concentrate diet fed to the calves in this present study

deciduous trees growing in close proximity to this paddock. The low clover and high weed content of the pasture from paddock 10 was again a reflection of the short time this pasture had been sown.

3.2.3. Bulk Density of the Diets (kg DM/litre)

As it is difficult to obtain a meaningful value for the bulk density of pasture, the two diets, concentrate and pasture were photographed to allow a visual comparison to be made - see Plate 3.2. As both piles represent 1kg DM, the lower density of the pasture compared with the concentrate diet is well illustrated.

3.2.4. Apparent DM Digestibility of Pasture using Sheep

The results of this study are summarized in Fig.3.1. The results demonstrated that the digestibility of the pasture was reasonably constant for the first seven weekly periods; by which time the calves' digestibility trial had been completed. The drastic drop in the DM digestibility during the eighth period was the probable result of a sharp rise in the soil contamination of the pasture over this period. This rise in the contamination is indicated by the rise in the ash content of the daily pasture samples for this period (see Fig.3.2.) and was the result of a combination of two factors:

(i) the replacement of the Allen mower with the sickle-bar mower, resulting in the pasture being cut closer to the ground

(ii) a period of intensive rainfall which produced muddy conditions.

Pasture 1kg DM (17% DM)

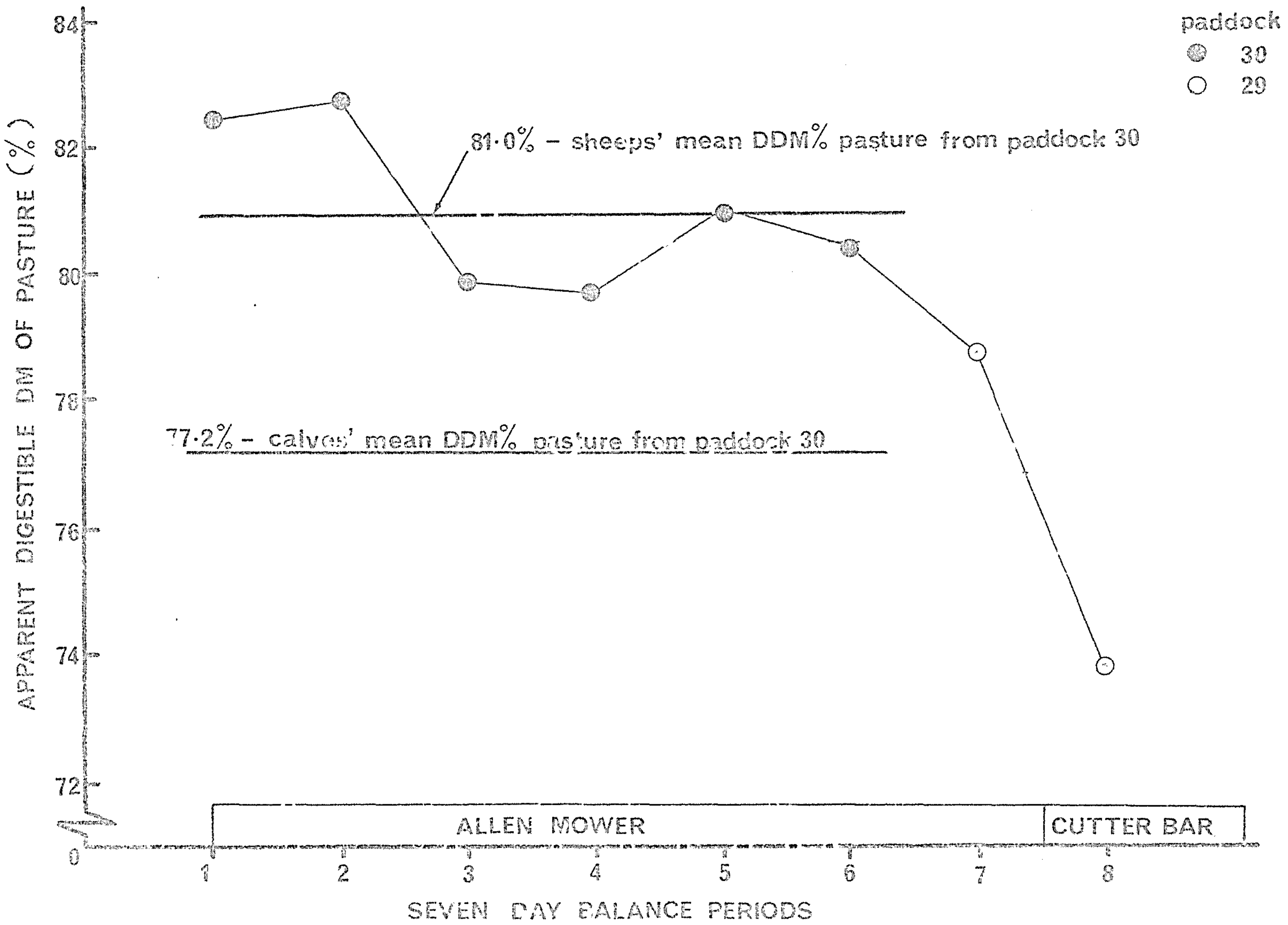
Concentrate 1kg DM (89% DM)

Plate 3.2. An Illustration of the Difference in Bulk Density between Pasture and Concentrate

For comparative purposes the mean DM digestibility of the pasture from paddock 30 for sheep and calves is also given in Fig.3.1.

In Fig.3.3. the use of the different paddocks for the supply of pasture, relative to the age of the calves is illustrated.

Figure 3.1. The DM digestibility of pasture using sheep



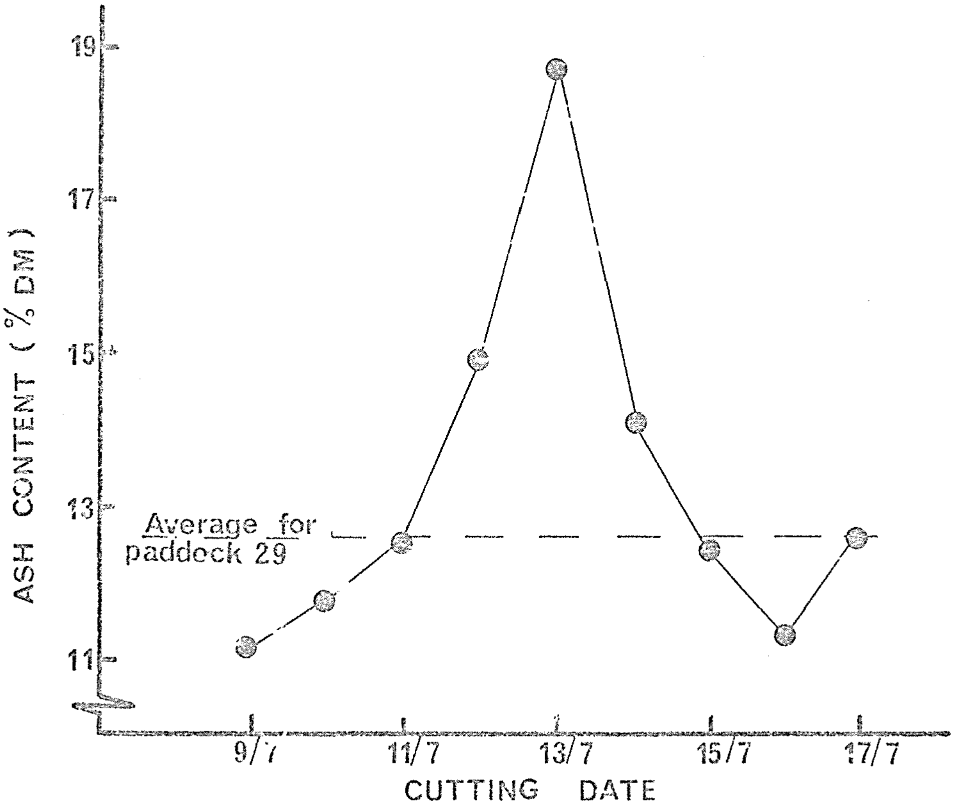


Figure 3.2. Daily ash content of pasture from paddock 29 showing increase in ash content due to soil contamination

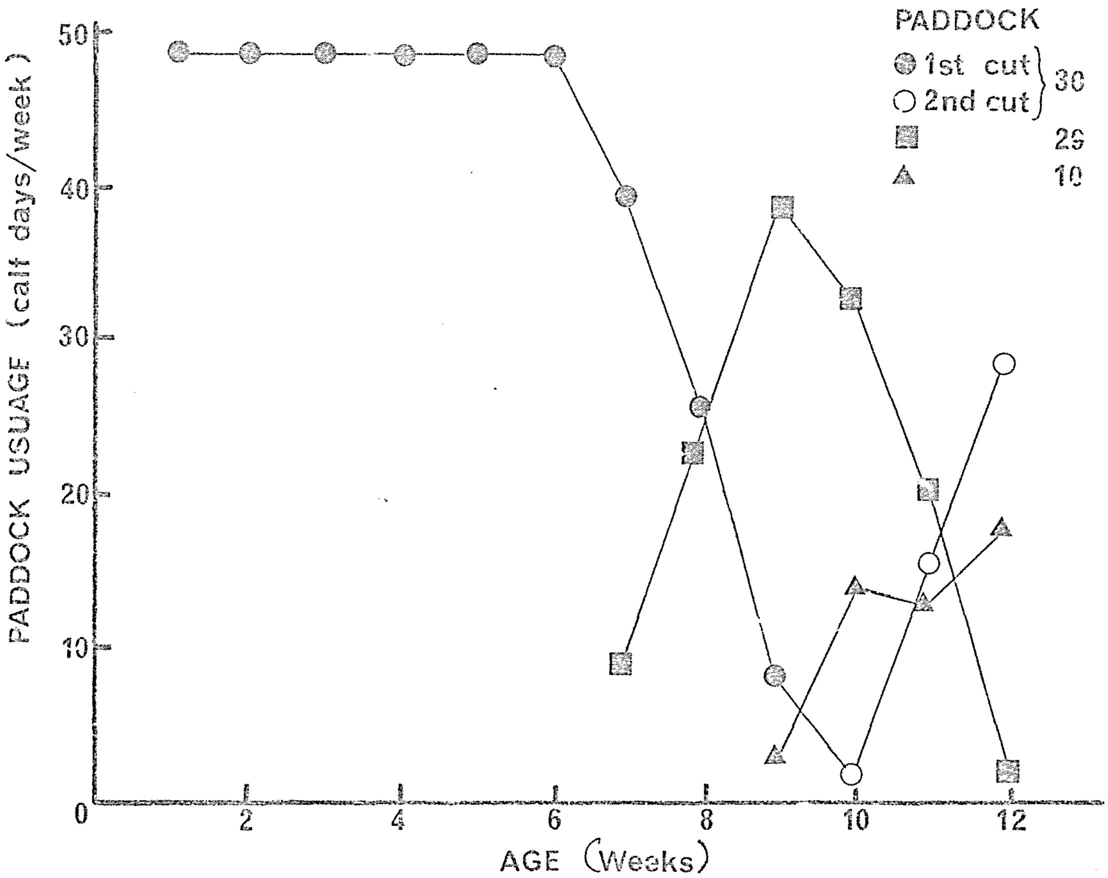


Figure 3.3. Paddock usuage during period A relative to age of calves

3.3. APPARENT DIGESTIBILITY DETERMINATIONS USING CALVES

The digestibility determinations of this present study were calculated on a one day 'lag' basis rather than the normal two day 'lag', as Preston et al. (1957) demonstrated that when young calves were fed pasture there was a maximum correlation between the intake of pasture and faecal output for a 'lag' of 24h. 'Lag' is defined as the time from when a particular day's feed was first offered until the corresponding day's faeces were collected. This result of Preston's was supported to a limited extent by the results of this present study (see Appendix III).

Apparent digestible energy (DE) determinations during the pre-weaning balance period (BP I) were calculated after correcting for the intake of milk, assuming the DE of cow's milk to be 95% (Tomme and Taranenko, 1939 cited by Roy et al., 1958).

The results of the digestibility trial are shown in Tables 3.3. and 3.4. By considering the figures obtained during the two consecutive seven-day sub-balance periods of BP I (pre-weaning - see Table 3.3.) and the four consecutive sub-balance periods of BP II (post-weaning - see Appendix IV) it was observed that the digestibility of the energy did not alter over the two balance periods.

TABLE 3.3. Apparent digestibility of energy (%) ± se of the pasture and concentrate diets offered to the calves when they were between 15 and 28 days of age (BP I)

1st sub-balance period	2nd sub-balance period	se of difference and probability of t-statistic (±)	(P)
75.53 ± 2.40	72.65 ± 1.66	2.27	NS
Combined data 73.71 ± 1.71			

As the DE coefficients of the diet fed to the calves during BP I were determined on varying levels of intake and varying ratios of concentrate to pasture, multiple regression analysis was performed to see if these two factors contributed to the variation of the DE values. The resulting regression coefficients along with their standard errors are given below, with neither of the coefficients being significantly greater than zero.

X_1 = intake $b_1 = 0.71 \pm 3.23$ (NS)

X_2 = concentrate/pasture $b_2 = 0.76 \pm 0.85$ (NS)

d.f. = 18

The difference between the DE coefficients of the pasture and the concentrate diets fed to the calves post-weaning (period A2) was non-significant (see Appendix IV). The individual calf determinations of the DE coefficients of the pasture and concentrate diets fed during this period are given in Table 3.4.

TABLE 3.4. Apparent digestibility of energy of the pasture and concentrate diets offered *ad libitum* to calves when they were from 36 to 57 days of age

Concentrate diet (Group C)		Pasture diet (Group P)	
Calf identification	DE (%)	Calf identification	DE (%)
1	73.63 b	2	74.82
3	74.83 b	4	76.98
5	68.70 a	6	73.69
7	76.58 b	8	76.64
9	77.50 b	10	73.68
Group mean ± se	74.25±1.54		75.16±0.71

a,b Values followed by a common letter for the DE values of group C are not significantly different ($P<0.05$).

The significance of the variation between calves in the determination of the DE coefficients of the two diets fed was investigated - see Appendix V. The variation between the calves receiving the pasture diet was non-significant. However the variation between the calves receiving the concentrate diet was highly significant, and a comparison of these calves' means by the least significant difference technique, demonstrated that the value for calf 5 was significantly lower compared with the others - see Table 3.4.

As the DE determinations during BP II were also carried out under varying energy intakes, the effect of this factor on the DE values within diets was investigated. With neither diet was the variation of the energy intake important in explaining any of the variation of the DE values. The results of this analysis are given in Table 3.5.

TABLE 3.5. Regression coefficients of the relationship between DE (Y,%) and energy intake (X,Mcal DE/day) analysed within diets

Diet	d.f.	b ± se	r^2	Prob. of b
Concentrate	18	−1.277 ± 3.815	0.01	NS
Pasture	18	−1.107 ± 0.686	0.13	NS

3.4. PERFORMANCE DATA

The performance results are presented in relation to the periods of the experiment. To give an overall perspective of the effects of the two rearing methods on the performance of the calves, the general results of period A are presented first, with the more detailed analysis of the sub-periods given in later sections.

3.4.1. Performance during Period A (0 - 84 days of age)

(i) Intake - the increase in the DM intakes expressed in absolute terms and relative to metabolic body size ($kg^{\frac{3}{4}}$) of the two groups of calves during period A, are given in Fig. 3.4. and 3.5. respectively. The source data for Fig's, 3.4. and 3.5. are presented in Appendices VI and VII respectively.

(ii) Daily live-weight gains - the mean live-weight gain (as calculated by the difference method) of the calves in group C during period A, was significantly greater ($P < 0.1\%$) than that of the calves in group P - see Table 3.6.

TABLE 3.6. Mean daily live-weight gain (kg/day) of the two groups of calves during period A (0-84days)

	Group C	Group P	se of difference and probability of t-statistic (±)	(P)
Live-weight gain(kg/day)	0.51	0.33	0.02	***

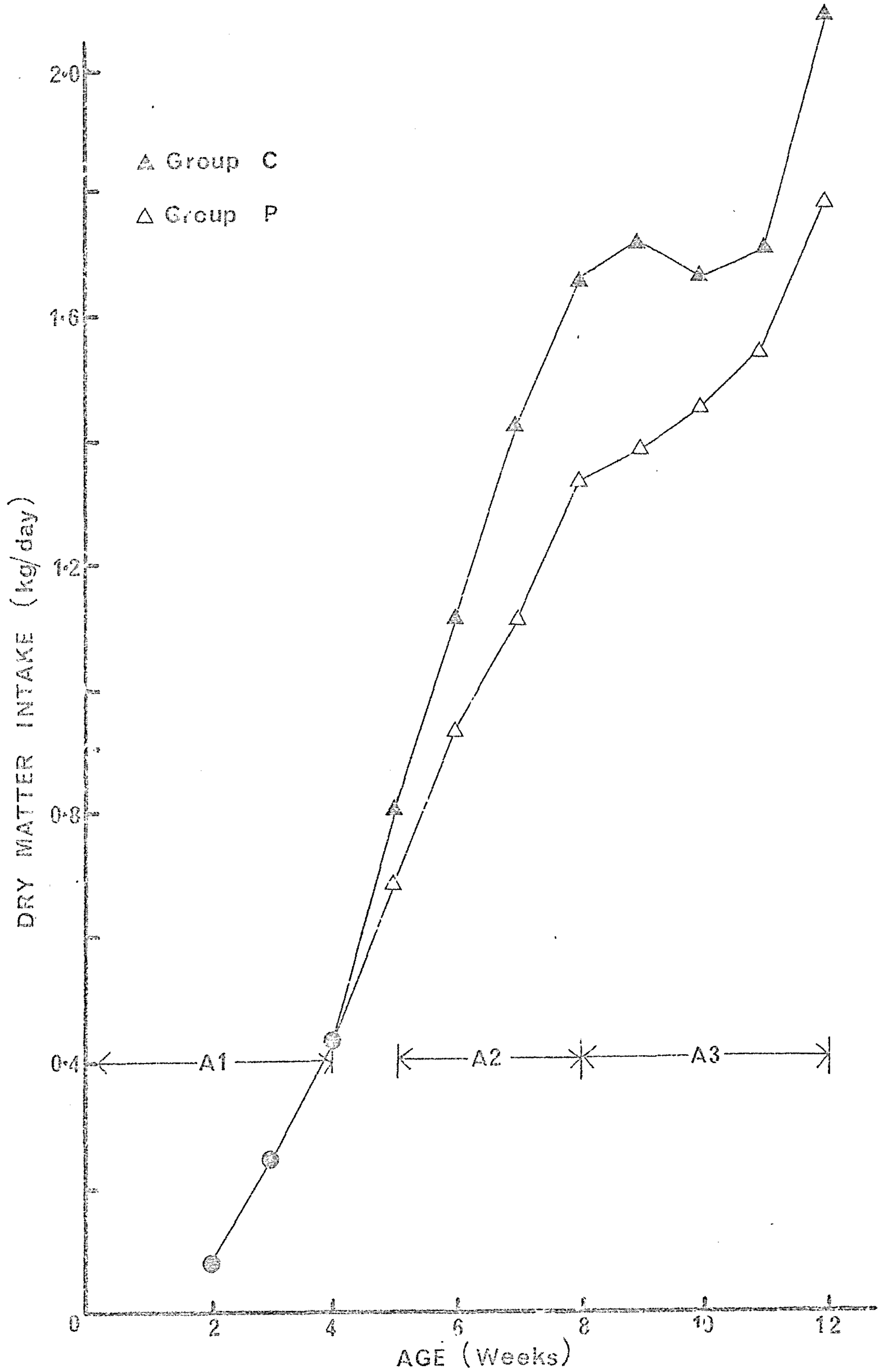


Figure 3.4. Group mean daily DM intake averaged over weekly periods during period A

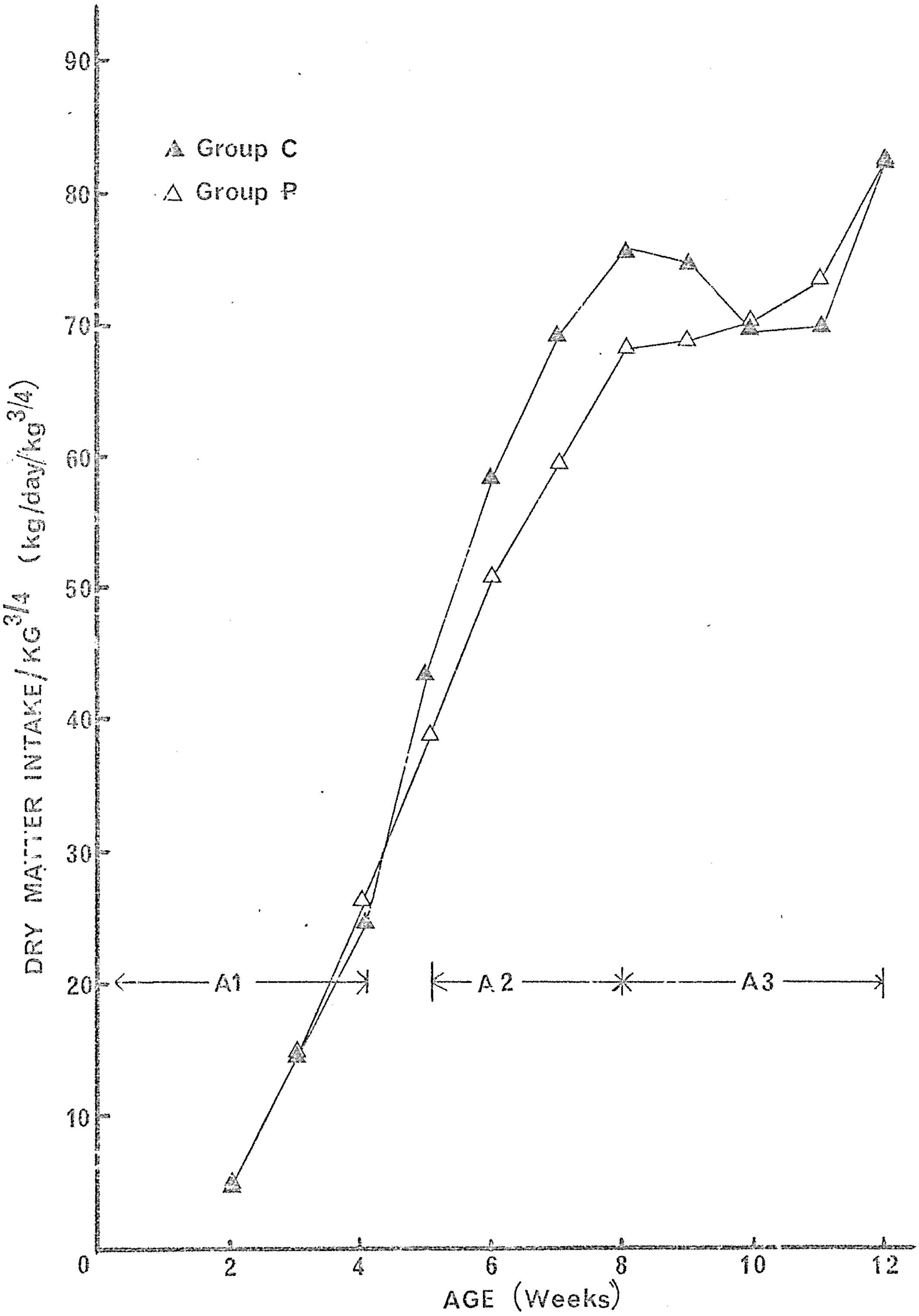


Figure 3.5. Group mean daily DM intake relative to metabolic body size averaged over weekly periods during period A

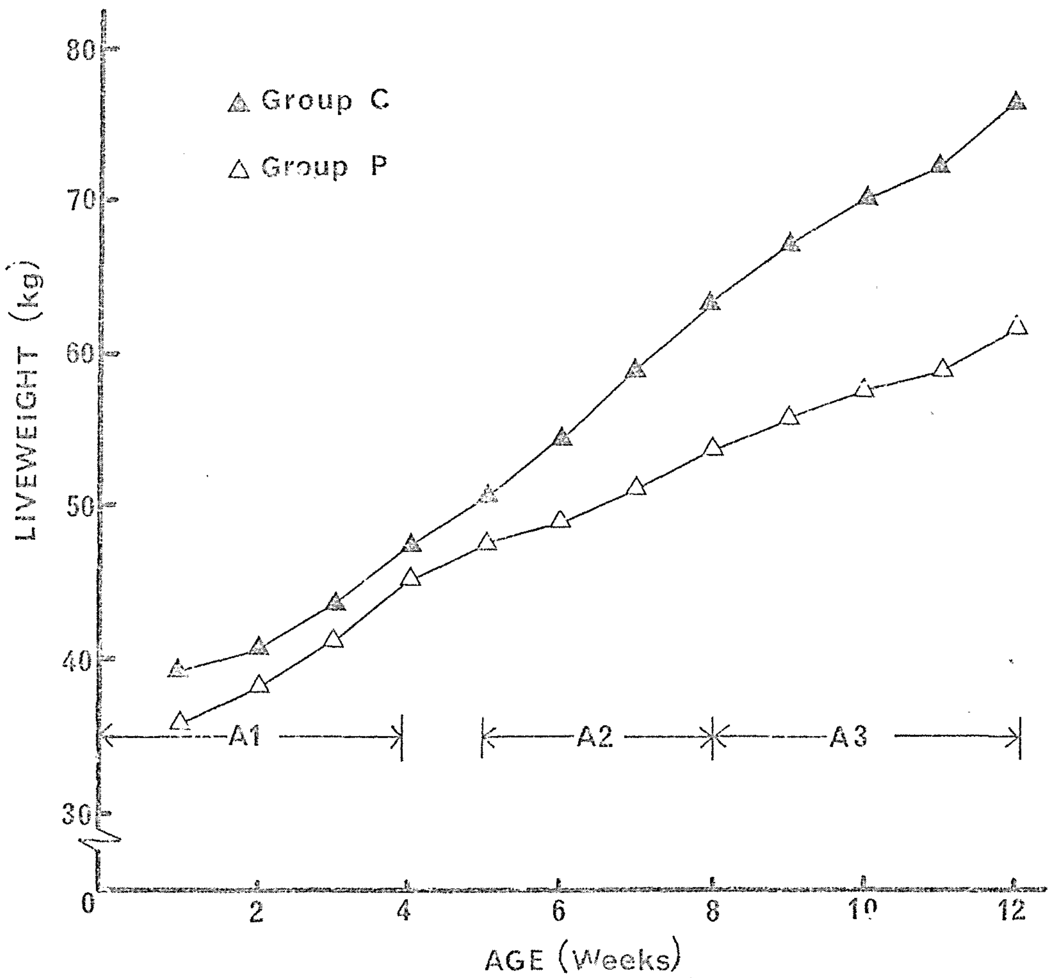


Figure 3.6. Group mean live-weight changes of calves during period A

(iii) Live weight - the mean live-weight changes of the two groups of calves during period A are illustrated in Fig. 3.6. These data are presented in Appendix VIII.

3.4.2. Performance during Period A1 (0 - 28 days of age)

The performance results of the two groups of calves during this period are summarized in Table 3.7.

TABLE 3.7. Performance (mean values) during the first four weeks of life of calves all offered pasture *ad libitum* and a restricted concentrate diet (after the first week) comparing the two groups to observe if any bias was introduced during this pre-weaning period which may have confounded the results of the calves' post-weaning performance

	Group		se of difference and probability of t-statistic	
	C	P	(±)	(P)
Weight at 1 week (kg)	39.0	36.4	2.0	NS
Intake of solid food(kgDM)				
Concentrate	3.568	3.525	0.781	NS
Pasture	1.731	1.858	0.427	NS
Total	5.299	5.383	0.636	NS
*Live-weight gain/day(kg)	0.40	0.42	0.04	NS

* Calves were receiving a milk allowance sufficient for maintenance + 0.2kg/day live-weight gain

The calves' intakes of solid food were expressed in terms of DM, as over this period the composition of their total DM intakes varied i.e. ratio of concentrate to pasture (see Fig. 3.7.) and the DE coefficients for these varying diets were too inconsistent for general application.

Disregarding groups, the total DM intake of pasture compared with concentrate by the calves during period A1 was investigated. The results are summarized in Table 3.8. demonstrating that when calves were offered both the concentrate and the pasture diets, they ate significantly more of the concentrate.

TABLE 3.8. Total DM intakes (mean values) of concentrate and pasture by calves during the first four weeks of their lives, when each calf was offered both diets, concentrate (restricted) and pasture (<u>ad libitum</u>)

	Diet		se of difference and probability of t-statistic	
	Concentrate	Pasture	(±)	(P)
Calves' mean DM intake (kg)	3.547	1.795	0.428	***

As there was a considerable variation between calves in the proportions of concentrate and pasture making up their total DM intakes (see Fig. 3.7.) the data was subjected to regression analysis (concentrate intake, Y; pasture intake, X) to investigate the possibility of any relationship between the

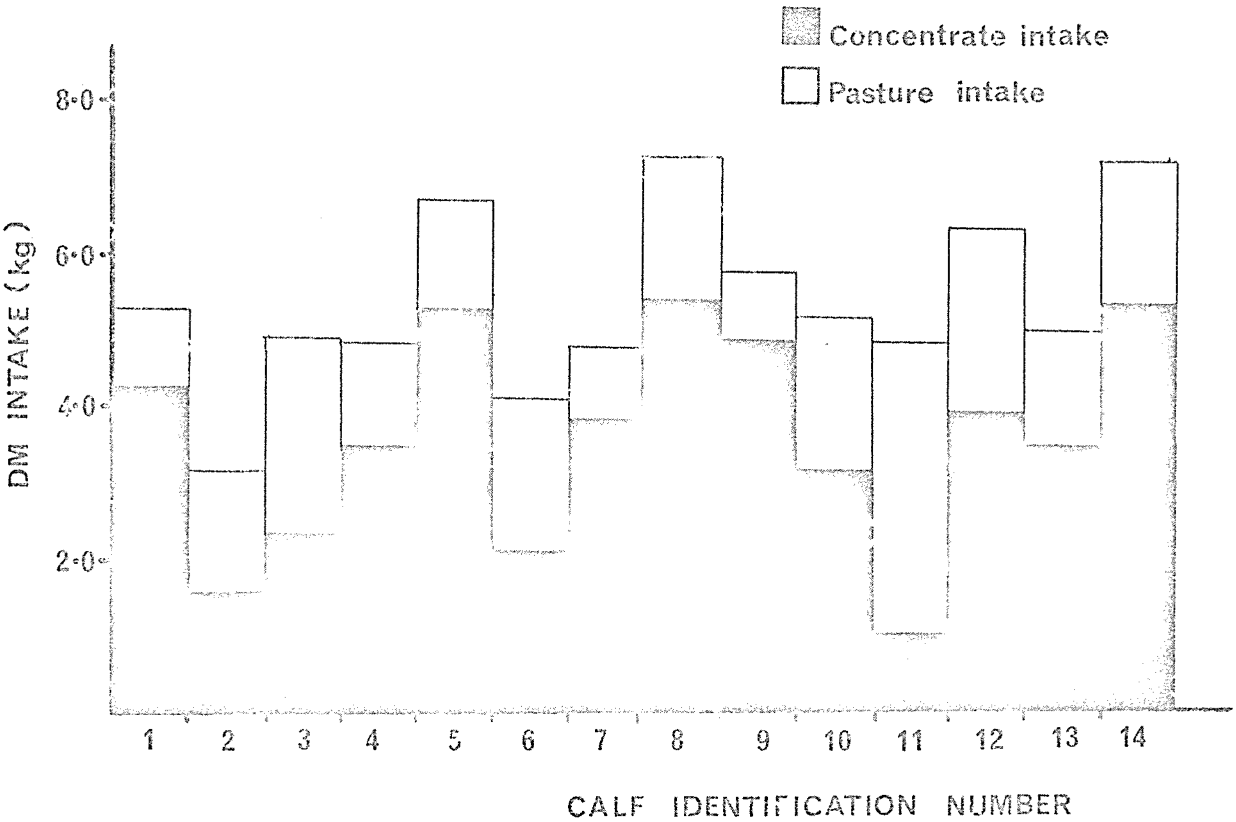


Figure 3.7. Composition of total DM intake of each calf during period A1

two variables. The results are given below:

$$a \pm se = 5.448 \pm 0.763 \quad (***)$$

$$b \pm se = -1.059 \pm 0.429 \quad (** \ )$$

$$r^2 = 0.34$$

d.f. = 12

Although b is close to unity, the 5% confidence interval for β is

$$-0.124 \geq \beta \geq -1.994$$

In interpreting the results of this comparison of the calf's relative intake of concentrate to pasture, it must be remembered that the calf's intake of concentrate was being restricted.

The relationship among the combinations of the three variables. live weight of the calves at one week of age, their respective total DM intakes of solid food and live-weight gains over the subsequent three weeks were investigated. The results are summarized in Table 3.9.

TABLE 3.9. Regression coefficients among the combinations of the variables, live weight of the calves at one week of age, their respective total DM intakes of solid food and live-weight gains over the subsequent three weeks

	Dependent variables			
	Live-weight gain (kg/day)		Total DM intake (kg)	
Independent variables	b ± se	r^2	b ± se	r^2
Live weight at 1 week (kg)	−0.001 ± 0.006	−0.003	0.053 ± 0.087	0.030
Total DM intake (kg)	0.737 ± 0.318*	0.310		

d.f. = 12

* significant at 5% level

3.4.3. Performance during Period A2 (35 – 56 days of age)

The calves' intakes of the two diets fed were expressed in terms of DE intakes with units of Mcal DE/day. These DE intakes were calculated from the gross energy intakes using the following DE coefficients:

(i) for the pasture diet – because the between calf variation of the DE coefficients for the pasture diet was not significant (see Appendix Va), the group mean was used as the estimate of the DE coefficient for the pasture fed to the calves.

(ii) for the concentrate diet - because the between calf variation of the DE coefficients for the concentrate diet was significant (see Appendix Vb), where present the calf's own estimate of the DE coefficient for the concentrate was used. For the two calves which were not involved in the digestibility study the group mean was used.

The calves' performance results for this period are summarized in Table 3.10.

TABLE 3.10. Performance (mean values) during the period of age of five to eight weeks of calves weaned by five weeks of age onto a diet of either concentrate (group C) or pasture (group P) offered ad libitum

		Group C	Group P	se of difference and probability of t-statistic (±)	(P)
DE intake of diet(Mcal/day)					
during the	6th week	3.802	3.261	0.247	*
	7th week	4.784	3.821	0.181	***
	8th week	5.519	4.535	0.255	**
Water intake/day (kg)		3.81	1.06	0.40	***
Live weight at	5weeks(kg)	50.8	47.3	2.0	NS
	8weeks(kg)	63.0	53.8	1.7	***
Live-weight gain/day (kg)		0.58	0.31	0.06	***

Although the calves in group C had a significantly greater daily water intake than the calves in group P, because the DM content and average DM intake of pasture by the calves in group P during period A2 was respectively 17.3% and 1.016 kg DM/day, these calves in addition to the water they drank took in 4.86 kg/day of water associated with the pasture.

The rates at which the calves increased their DM intakes of solid food with time during periods A1 and A2 were calculated by regressing the DM intake of solid food (Y, kg DM) on the age of the calf (X, weeks) and using the regression coefficient (b) as the estimate for the rate of increase. The results of the analysis are summarized in Table 3.11.

TABLE 3.11. The rates at which the calves increased their DM intakes with time (kg DM/week) of the concentrate/pasture diet they all received during the pre-weaning period (period A1) and the pasture (group P) and the concentrate (group C) diets they received post-weaning (period A2)

Period	d.f.	Groups C	Groups P	level of significance between groups
A1	40	0.179 ± 0.014		
A2	33	0.306 ± 0.023	0.220 ± 0.016	**
level of significance between periods		***	NS	

The results demonstrate that the calves receiving the concentrate diet post-weaning were able to both increase their DM intakes at a significantly greater rate that those receiving pasture, and also at a greater rate than during the pre-weaning period. Calves receiving pasture post-weaning were not able to significantly increase their rate of increase in DM intake during this post-weaning period compared with the rate for the pre-weaning period.

The maintenance requirement for the young calf was estimated by Johnson (1972) to be 110cal ME/kg $^{0.73}$ and by dividing this value by the constant 0.82 to convert ME to DE (ARC, 1965; Fennessy, Woodlock and Jagusch, 1972) an estimate for the calf's maintenance requirement in terms of DE is derived; namely 134 kcal DE/kg$^{0.73}$. This value was used to remove the maintenance component from each calf's average daily DE intake for period A2. The relationship between the resulting residual DE intake, which theoretically would be that DE intake available for production, and the live-weight gain of the calves over this period was investigated. The analysis is given in Table 3.12., while the relationship is illustrated in Fig. 3.8.

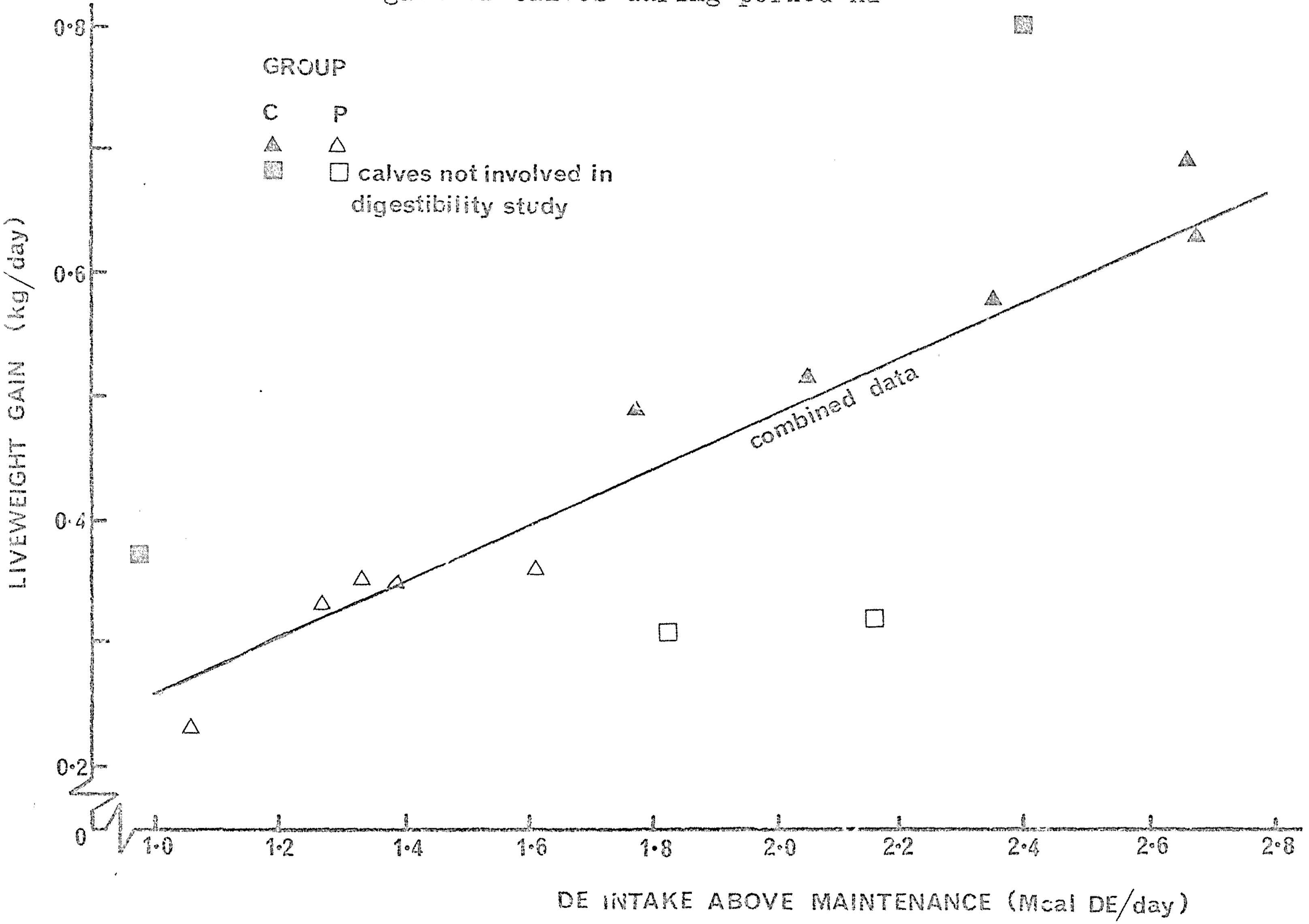
TABLE 3.12. Regression coefficients for the relationship between daily live-weight gain (Y, kg/day) and DE intake above maintenance (X, Mcal DE/day) when calves, during the period of age of five to eight weeks were offered either a pasture (group P) or concentrate (group C) diet <u>ad libitum</u>

	d.f.	a ± se	b ± se	r^2	sig. of b
Group P	6	0.267 ± 0.126	0.0359 ± 0.0499	0.09	NS
Group C	6	0.186 ± 0.078	0.1845 ± 0.0569	0.68	*
Combined data of groups P and C	12	0.034 ± 0.096	0.2273 ± 0.0499	0.64	***

The analysis of the combined data from both groups demonstrated a highly significant relationship between the live-weight gains of the calves and their DE intakes above maintenance. A significant relationship was also demonstrated for the calves receiving the concentrate diet, but not for the calves fed pasture. The four calves which deviated most from the common regression line were those calves which were not involved in the digestibility study. A possible implication of this is discussed later (see section 4.1.2.)

The reciprocal of the regression coefficient b, gives an estimate of the energy allowance for growth. For the combined data the reciprocal of b=4.399 Mcal DE/kg live-weight gain.

Figure 3.8. Relationship between DE intake above maintenance and live-weight gain of calves during period A2



3.4.4. Performance during Period A3 (57 - 84 days of age)

It is illustrated in Fig. 3.4. that when the calves in group C were changed from the concentrate diet to pasture, their increase in DM intakes with time decreased markedly. This result however, has limited interpretation as

(i) there was not a control group of calves fed the concentrate diet concurrently to the time of change over of the two diets, the extent of the effect of this change over cannot be truely assessed

(ii) the results were confounded by a decrease in the quality of the pasture supply over this period, brought about by the predominant use of the pasture from paddock 29 at this time (see Fig.3.3.). This fall off in quality was reflected by a decreased rate of increase over this period of the DM intake of calves fed pasture (group P) - see Fig. 3.4.

To assess the effect of the feeding of the concentrate diet to the calves in group C during period A2 on their subsequent intake of pasture, the pasture DM intakes expressed in absolute terms and also relative to metabolic body size of the calves in the two groups during week twelve were compared. The results are presented in Table 3.13. and show that provided allowance was made for the live weight differences between the calves in the two groups, there was no significant difference in the intake of pasture between these two groups of calves.

TABLE 3.13. Daily DM intake of pasture expressed in absolute terms and relative to metabolic body size ($kg^{\frac{3}{4}}$), when offered <u>ad libitum</u> to calves during their twelfth week of life

	Group		se of difference and probability of t-statistic	
	C	P	(±)	(P)
DM intake (kg/day)	2.086	1.781	0.124	*
DM intake/$kg^{\frac{3}{4}}$ (kg/$kg^{\frac{3}{4}}$/day)	82.47	82.50	4.87	NS

3.4.5. Performance during Period B (84+ days of age)

The live-weight changes of the two groups of calves during period B are summarized in Table 3.14. and Fig. 3.9. At no time during this period did the difference in live-weight gains between the two groups differ significantly, resulting in the difference in live-weight established when the calves were twelve weeks of age being maintained throughout the period of measurement.

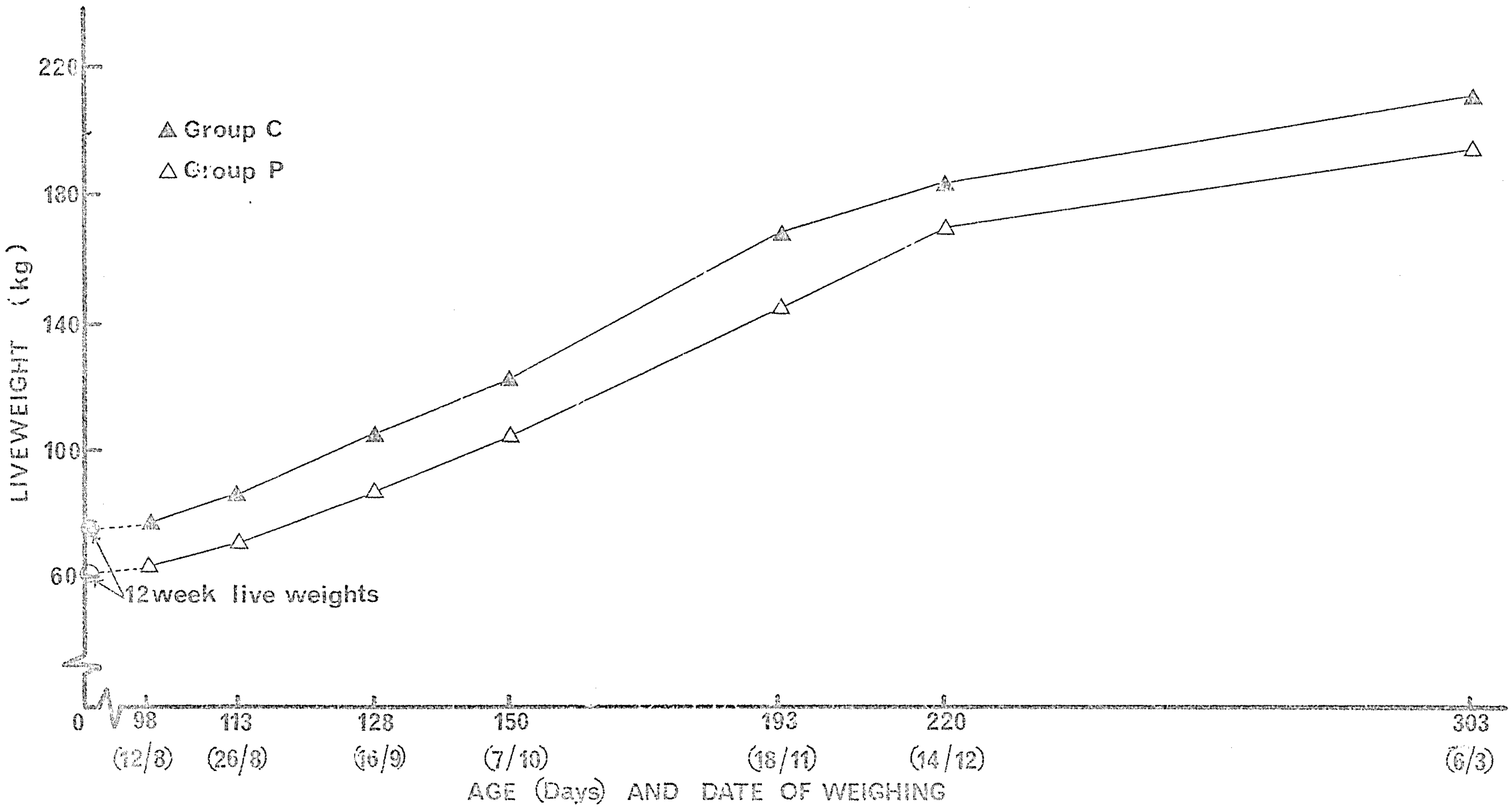
TABLE 3.14. Daily live-weight gain of calves during the period of age of 84 to 303 days when they were grazing pasture

Period of growth	Age* (days)	No. of calves	Groups C	Groups P	se of difference (±)
12 - 26/8	113	14	0.62	0.54	0.10
27/8 - 16/9	128	12	0.83	0.78	0.08
17/9 - 6/10	150	11	0.81	0.82	0.04
7/10 - 18/11	193	11	1.07	0.97	0.06
19/11 - 14/12	220	11	0.61	0.56	0.10
15/12 - 6/3	303	9	0.35	0.42	0.06
over all 12/8 - 6/3		9	0.65	0.64	0.04

no significant differences in this table

* Average age of calves at end of period

Figure 3.9.   Group mean live-weight changes of calves during period B



3.5. RETENTION TIMES OF DIET RESIDUES

The mean retention times for the two diets averaged over the four calves, are given in Table 3.15. The difference between the two means was not significant. The average cummulative curves for the two diets are given in Fig. 3.10.

TABLE 3.15. Time of retention of undigested residues of the pasture and concentrate diets fed during period A2

	Concentrate	Pasture	se of difference and probability of t-statistic (±)	(P)
Mean retention time (h)	68.5	69.0	3.9	NS

As the staining method extracts soluble material and removes small particles from the diets, the stained diets were analysed for their content of acid detergent fibre (cellulose + lignin) to assess the extent of this extraction. These results, compared with the acid detergent fibre content of the corresponding unstained diets are given in Table 3.16. and a large difference noted.

TABLE 3.16. Acid detergent fibre (% of DM) of the stained and unstained diets fed to the calves

	Acid detergent fibre (% of DM) of	
	Concentrate	Pasture
Unstained	9.7	20.6
Stained	25.3	36.5

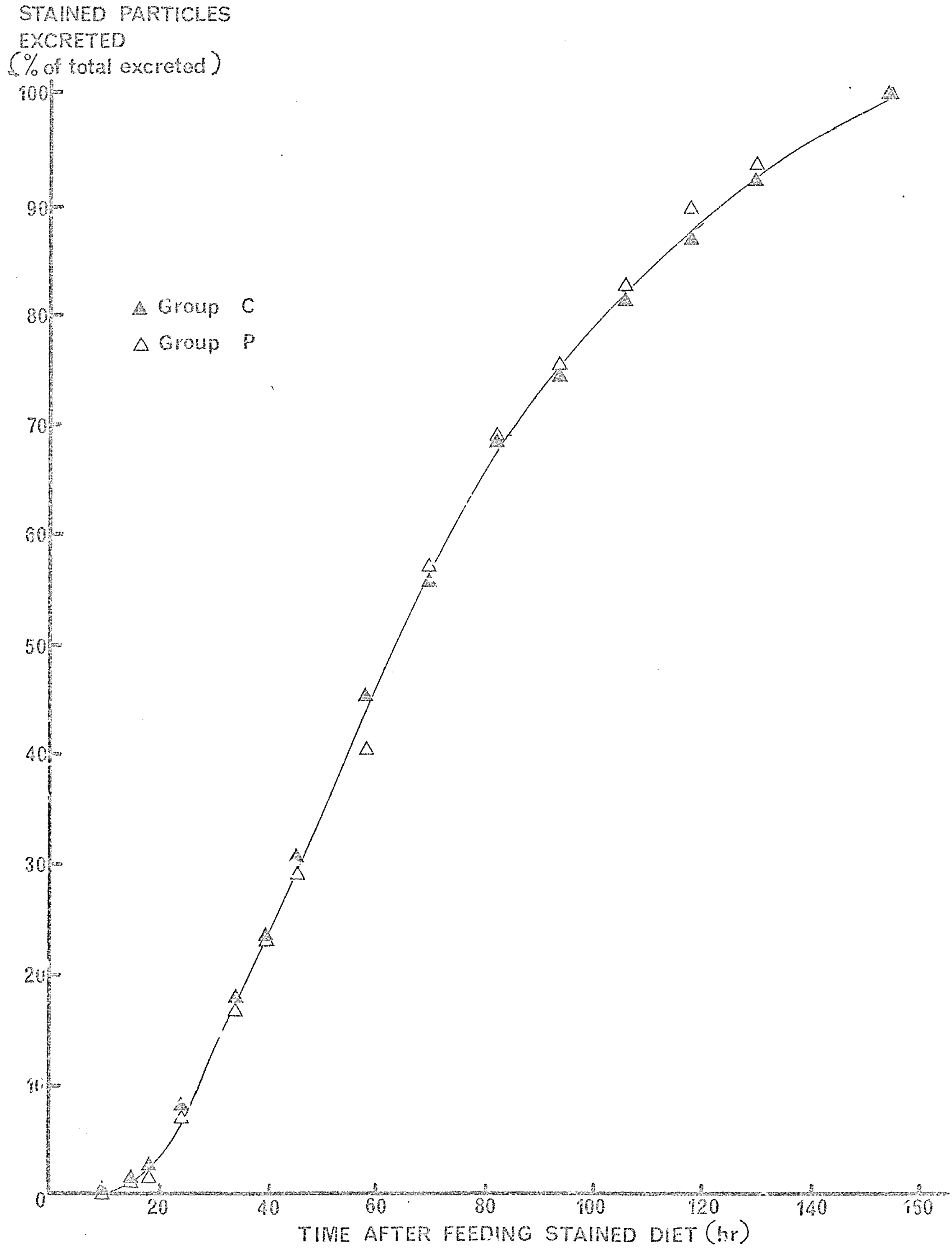


Figure 3.10. Curve of excretion of undigested residue of the two stained diets by calves

3.6. FEEDING BEHAVIOUR

The individual and group means for the time spent eating and ruminating by the calves receiving either the concentrate or the pasture diet are given below in Table 3.17.

TABLE 3.17. Individual and group means for the feeding behaviour of calves aged between six and eight weeks receiving a diet of either concentrate or pasture

	Calf No.	No. of records /animal	Time spent in Eating (h)	Eating (min/gDM)	Ruminating (h)	Ruminating (min/gDM)
Group C	11	5	3.13	0.16	7.71	0.39
(Concentrate)	13	9	3.10	0.13	5.45	0.23
Group mean			3.12	0.14	6.58	0.31
Group P	10	9	6.64	0.34	6.70	0.34
(Pasture)	12	9	6.73	0.29	6.97	0.30
	14	2	6.69	0.29	7.92	0.35
Group mean			6.69	0.31	7.20	0.33

Owing to the limited data, differences between groups in feeding behaviour were not tested statistically. However, it is obvious that the calves receiving pasture spent considerably more time eating than those receiving concentrate, although the time spent ruminating was fairly similar.

The distribution of the eating, ruminating and resting activities of the calves throughout the day is given in Fig. 3.11. The results demonstrate the periodicity of these activities, with eating being more predominant during the day while ruminating more at night.

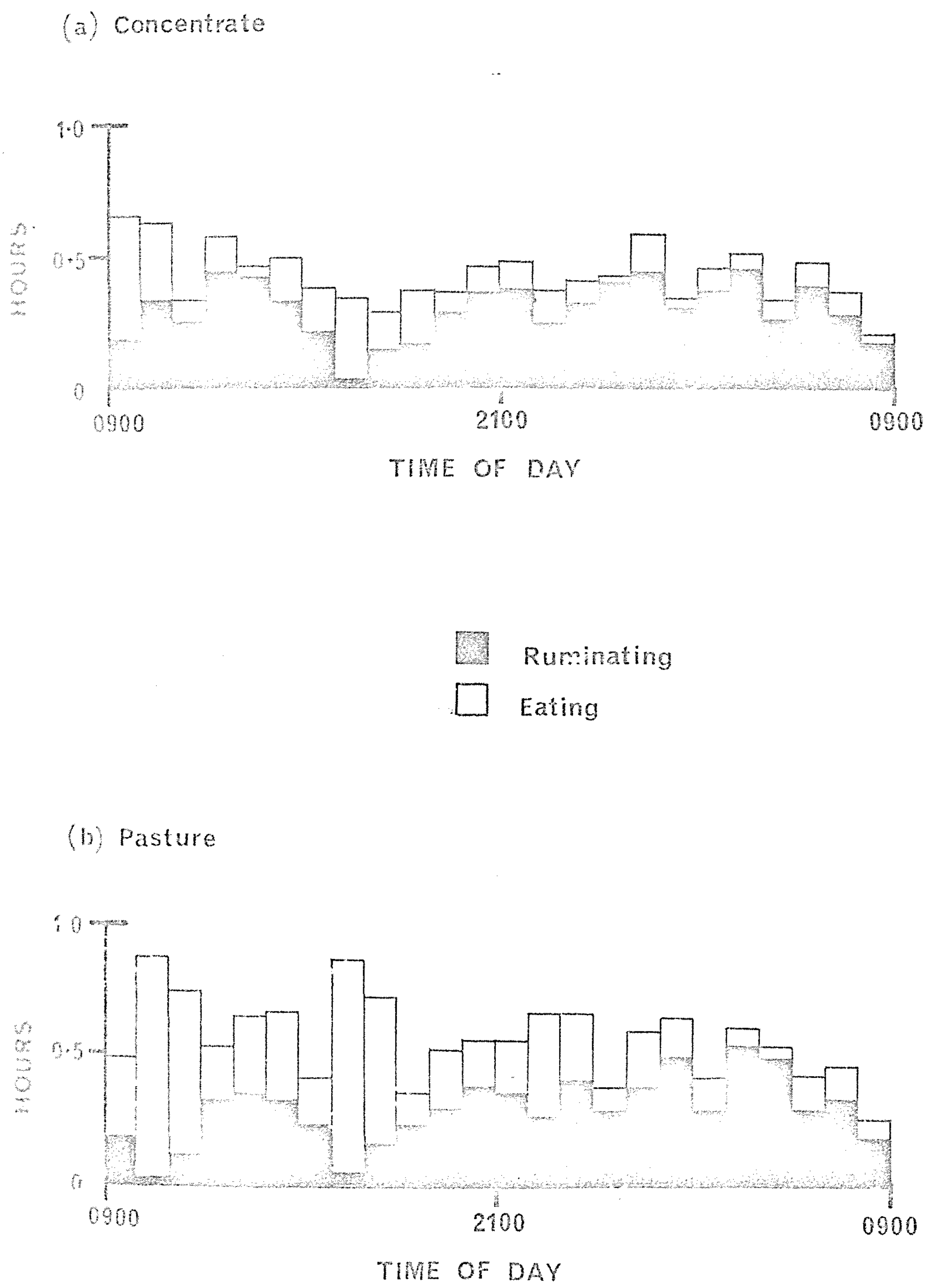


Figure 3.11. The distribution of eating, ruminating and resting activities of calves throughout the day

CHAPTER FOUR

DISCUSSION

4.1. THE COMPARISON OF PASTURE AND CONCENTRATES AS EARLY-WEANING FOOD FOR CALVES

4.1.1. Intake and Live-weight Gain of Calves

In the present study calves were weaned onto either concentrate or pasture when they were five weeks old and their performance for the subsequent three weeks was investigated. The results demonstrated that during this post-weaning period, the calves receiving pasture had significantly lower DE intakes and live-weight gains compared with the calves receiving the concentrate diet (see Table 3.10.). This result is in agreement with results obtained by Spedding et al.(1963), Brown (1964) and Large and Spedding (1964) with lambs and Gleeson (1972) with calves.

It is unlikely that the lower intakes of the calves receiving pasture compared with those receiving concentrates during the post-weaning period, could be attributed to the pre-weaning management. The pre-weaning management of the calves resulted in both groups having similar mean DM intakes and live-weight gains for the period (see Table 3.7.). This result was important in the view of the discussion in section 1.2.3.3. on the effect of the level of intake of solid food over the pre-weaning period on the intake of solid food during the post-weaning period. The other important point about the pre-weaning management was that the calves gained experience in eating their respective post-weaning diets prior to weaning. This avoided the possibility that the difference in intake of the two diets fed during the post-weaning was influenced by prior experience of the food. That the prior experience gained with a food affected the subsequent intake of that food by calves was observed by Hodgson (1970a) - see also section 1.2.3.3.

The initial live weights of the calves in this study, which ranged from 30.2 to 43.4kg, did not have an influence on the subsequent performance of the calves during the pre-weaning period (see Table 3.9.). This result supports the observations of Lawrenece and Pearce (1965), Davies and Owen (1967) and Kay (1969) - see section 1.2.3.1.

In the present experiment the growth rates of the calves receiving pasture during the post-weaning period were similar to those obtained by Gleeson (1972); namely 0.31 and 0.37kg/day respectively. Both results, however, were lower than those of Longsdale and Tayler (1969) who obtained growth rates of calves receiving pasture in the order of 0.5kg/day. This difference in growth rate may have arisen through the calves, both in this present experiment and that of Gleeson (1972), receiving cut pasture indoors, whereas Longsdale and Tayler's (1969) calves grazed pasture. It is well known that calves are selective grazers (Hodgson, 1968) and it may have been that the reduction in selection caused by stall-feeding the calves cut pasture, did not allow the true potential of pasture as an early-weaning food to be realised. Therefore, although the mean growth rate of the calves receiving pasture in the present study of 0.31kg/day was well below the "target" for dairy repacement stock of 0.45 to 0.55kg/day (McMeekan, 1956; Crichton et al., 1959), this study does not necessarily discount pasture as an early-weaning food for this type of stock.

The mean growth rate of the calves receiving the concentrate diet of 0.58kg/day was below expectation, as Khouri (1969) who weaned calves onto a similar concentrate diet, obtained growth rates of 0.77kg/day. The difference may have arisen through the calves in the present study being subjected to a pre-weaning feeding regime of restricted concentrate and ad libitum pasture. As it was illustrated in Table 3.8. that the calves appeared to have a greater ability to take in concentrates compared with pasture during the pre-weaning period, it is likely that these calves would have had a lower DM intake than if they were being fed concentrates ad libitum, as did Khouri (1969). This may have resulted in a difference in performance in view of the carry-over effect of the pre-weaning management on the post-weaning performance (see section 1.2.3.3.).

The lower DM intake of pasture compared with concentrates during the pre-weaning period, when the calves were offered both diets, was not reflected in the relationship between each calf's intake of concentrate and its intake of pasture (see page 69). The estimate of the regression coefficient, β, for this relationship was -1.059 which would suggest that the calves substituted pasture for concentrates on a 1:1 basis. However, this interpretation must be treated with caution in view of the large 5% confidence interval associated with the estimation of β.

4.1.2. Digestibility

The results of the post-weaning digestibility study demonstrated that the DE content of the pasture and the concentrate diets fed to the calves over this period were very similar (see Table 3.4.). This result suggests that the difference between the calves' intake of the pasture and the concentrate diets did not arise from a difference in the digestibility between the two diets. That the difference in intake could not be explained in terms of a difference in digestibility between the two diets is not unexpected as Raymond (1969) has pointed out that a general relationship between intake and digestibility is a too simplified concept. Further, Montgomery and Baumgardt (1965b) have suggested that the relationship between intake and digestibility may differ according to the physical form of the diet and its density.

The calves' ability to digest the pasture and concentrate diets developed early. This was demonstrated by the high coefficients of the DE of the concentrate/pasture diet fed during the pre-weaning period (see Table 3.3.) and also by the absence of any significant alteration in the DE coefficients between the various sub-balance periods (Table 3.3. and Appendix IV). This confirms the result of Preston et al. (1957) that calves develop the ability to digest solid food at a very early age. In the present study the calves were two weeks old and had been receiving solid food in addition to the milk allowance for a period of one week when the digestibility study started.

The slightly higher DM digestibility of the pasture determined with sheep compared with that of the calves (see Fig. 3.1.) was probably associated with the different levels of feeding of the two groups of animals. Whereas the calves received pasture ad libitum, the sheep were fed a ration of pasture sufficient only for maintenance. In this regard Raymond and Minson (1959) and Anderson, Reid, Anderson and Stroud (1959) with sheep, demonstrated a drop in digestibility of pasture with an increase in intake.

An apparent contradiction of these results is that the variations in the level of intake between calves were not reflected in variations in digestibility (see Table 3.5.). Leaver, Campling and Holmes (1969) suggest that gut capacity is important in determining the extent of the effect of the level of feeding on digestibility in a particular animal. Also, over the transitional phase of the calf's life (which corresponds to the post-weaning period of the present study) there is a close relationship between rumen size and DM intake of solid food (Stobo, Roy and Gaston, 1966; Hodgson, 1971bc). Possibily therefore, the ratio of the calves' intakes expressed as some unit of their gut capacity may approach a constant. In view of the conclusions of Leaver et al. (1969) this would be reflected in an absence of a relationship between the level of feeding and the digestibility.

The standard errors associated with the group mean digestibilities of the concentrate and pasture diets are low considering that this digestibility study varied from the classical technique (Watson and Horton, 1936) which requires that the intake of food of the experimental animals be maintained constant over the entire period of the trial; a situation which was impractical for the purpose of this experiment. The larger between calf variation associated with the estimate of the DE of the concentrate diet was due mainly to a low value associated with calf 5 (see Table 3.4.). The reason for this low value is not known, although the faeces of this particular calf had a distinctive putrificative smell, not present with the other calves, perhaps indicating a possible digestive disorder.

4.1.3. Relationsip between DE Intake above Maintenance and Live-weight Gain during the Post-weaning Period

A highly significant relationship, using the pooled data, between DE intake above maintenance and live-weight gain was established. There are two points which arise from this analysis.

(i) The fact that a common regression line can fit the data from both groups would suggest that the two diets were utilized with equal efficiency in promoting live-weight gain of the calves. This again highlights the fact that the important difference between pasture and concentrates as an early-weaning food for calves is one of intake and not one of quality.

(ii) The good fit of most of the data to this common regression line would suggest that the relative difference between the live-weight gains of the two groups of calves for the post-weaning period was not confounded to any real degree by a relative difference in gut fill between the two groups.

The greatest deviation from the common regression line occurred with the four calves not used in the digestibility study. Whether this was coincidental or not is debatable, however, it is of interest that the intakes of three of these four calves represented extreme intakes for their respective groups. Although it was concluded in section 4.1.2. that the variation in the intakes of the calves did not have a significant affect on the digestibility of the diets fed, the extreme manner in which the intakes of these three calves deviated from the mean may have resulted in some effect on the digestibility of the diets. This would have made it erroneous to apply the group mean digestibilities to calculate the DE intakes for these calves. However, whether this was the major cause for the marked variation of these values or whether it was due to gut fill factors or other more obscure factors is mere spectulation.

As stated in section 3.4.3. the reciprocal of the regression coefficient (1/b) gives an estimate of the DE requirement for the live-weight gain of the calves over the post-weaning period, when using the figure of 110kcal/ME/kg$^{0.73}$ /day as the estimate of the calves' maintenance requirement (Johnson, 1972). In this present study the DE requirement for growth was calculated to be 4.399 Mcal DE/kg live-weight gain. As Johnson (1972) did not publish any figures for the calves requirements for growth when receiving a diet of solid food, it was not possible to compare directly the value obtained in this present study with his results. However, it is probable that the requirement for growth calculated in this present experiment is an underestimation of the "true" value. This is because the calves' absolute live-weight gains over this period are confounded by concomitant increases in gut fill. This increase in gut fill is illustrated by the results of Roy and Stobo (1963). They found that the weight of the contents of the alimentary tract increased from 6% body weight when calves three weeks of age were receiving a liquid diet, to 27% and not less than 11% of body weight when calves twelve weeks of age were receiving respectively a roughage or a concentrate diet offered ad libitum . The calves were weaned at five weeks of age.

4.1.4. Feeding Behaviour

The present study confirms the results of other peoples' work, summarized in Table 1.1., that calves receiving pasture spend a considerable time eating and ruminating. Calves receiving a concentrate diet, spent less time eating and ruminating per unit DM intake than calves receiving pasture (Table 3.12.), with the greater difference occurring with time spent eating than ruminating. The unexpectedly high ruminating times for the calves receiving the concentrate diet was probably because of the small amount of pasture fed (8 - 10% DM intake) along with the inclusion of 10% chopped hay in the concentrate diet.

In view of the probable importance of oropharyngeal factors in controlling the intake of solid food by young ruminants shortly after weaning (see section 1.1.1.), the possibility arises that the difference between the intake of concentrates and pasture by the calves in the present study may have been attributable to the calves having to spend more time eating and perhaps ruminating per unit DM intake when receiving pasture than when receiving concentrates. This would operate through oropharyngeal factors placing an upper limit on the time the calf is willing or able to eat and ruminate. Therefore because calves receiving pasture must spend a longer time eating and ruminating per unit DM intake compared with those calves receiving concentrates, they will reach the limits imposed on intake by the oropharyngeal factors at a lower intake, compared with those receiving concentrates.

4.1.5. Mean Retention Time of the Concentrate and Pasture Diets

The results of this study would suggest that the undigested residues of the concentrate and pasture diets spent an equally long time in the gut of the calf (Table 3.15.). However, in comparison with the results of various other workers (see Table 4.1.) two important points arise with regard to the results of this study.

(i) The mean retention times of the two diets in the present study were considerably higher than the results of other workers. Furthermore, it must be pointed out that the mean retention times in the present study were underestimated, as there was still a considerable amount of coloured particles present in the last faecal sample with each diet.

(ii) The similarities of the mean retention times of the two diets. This would not be expected considering the results of Taparia and Davey (1970), although similar times of

TABLE 4.1. Comparison of mean retention times of various diets

Animal	Diet		Mean retention time	Reference
Calf 6-8 weeks of age	Pasture		69.0	Present experiment
	Concentrates		68.5	
Calf 5-12 weeks of age	Dried grass	Long form	46.8	Hodgson (1971a)
		Ground pelleted	23.0	
		" "	23.0	
		Long form	58.5	Hodgson (1971c)
		Ground pelleted	29.2	
	Concentrates with increasing roughage	ME content 3.2	40.2	Kay *et al.* (1972)
		" 2.9	35.1	
		" 2.6	33.2	
Milking cow	Pasture		41.6	Taparia and Davey (1970)
	Concentrates		28.2	

rumination for the two diets (see section 4.1.4.) may give a clue as to the reason for the similarity of the results.

With regard to the technique of using coloured particles as a measurement of the mean retention time of a diet, Ellis and Huston (1968) seriously question the significance which can be attached to such flow data measurements in view of the extractive nature of the staining procedure. The extent of this extraction of the coloured particles used in the present study has been illustrated in Table 3.16. In relation to the acid detergent fibre component, the two stained diets bear little resemblance to the original diets. Therefore in view of the magnitude and the similarity of the mean retention times of the two diets, it is the writers' opinion that these two stained diets traversed the gut in a similar manner and relatively independent of dietary influence.

However, if one assumes that the data are correct and that they are a truc reflection of the mean retention times of the two diets, then the fact that they were similar does not discount the possibility that gut fill factors were a possible cause for the difference between the calves' intakes of the two diets. This is because, although the residues of the two diets spent an equally long time in the gut, pasture, being less dense (kg DM/litre) than concentrates (see Plate 3.2.), would have occupied a greater volume per unit DM intake within the gut for that period of time. Thus if gut fill factors were important in controlling the intake of solid food of calves shortly after weaning and if the mean retention times of the two diets were similar, because pasture is less dense than concentrates, the calves would have reached the limits imposed on intake by the gut fill factors at a lower DM intake of pasture than of concentrates.

4.1.6. Change Over from Concentrate to Pasture

A decrease in the live-weight gain was observed when the calves were changed from a predominantly concentrate diet to pasture alone. Unfortunately this part of the trial was confounded by a fall in the quality of the pasture supply, as has already been discussed in section 3.4.4. The results however, are in general agreement with Khouri (1969), Slade (1972)and Gleeson (1972) who also observed a drop in performance when calves, at a comparable age to those of the present study, were changed from a diet of concentrate to pasture.

The comparison of the voluntary intake of pasture of the two groups of calves during week 12, indicated that the intake of pasture was unaffected by the post-weaning treatments, provided allowance was made for live-weight differences (Table 3.13). That is, there were significant differences in intake between the groups, but these were consistent with the differences in live-weight. This result is in agreement with the results of Longsdale and Taylor (1969), Gleeson (1972) and Reardon and Everitt (1972) and perhaps points to the fact that compensatory growth during the recovery period in young calves appears to be less likely on bulky foods such as pasture, where the gastro-intestinal tract limits intake (Hodgson, 1968).

4.2. EFFECT OF REARING METHODS ON SUBSEQUENT GROWTH RATES OF CALVES

At no stage during the post-experimental period when the calves of both groups were treated similarly and were grazing pasture, were there significant differences between the growth rates of the two groups of calves (Table 3.14.). This is illustrated in Fig. 3.9. where the growth curves of the two groups of calves over this period were parallel, resulting in the difference established in live-weight, when the calves were twelve weeks old, persisting throughout the period of measurement. This result is in agreement with Wardrop (1966), Longsdale and Tayler (1969), Everitt (1972), Morgan (1972) and Reardon and Everitt (1972) and adds further support to the existing evidence that calves under-fed from an early age will not compensate by growing faster during the subsequent period.

This present study is in contra diction to the results of Davey (1962) whose calves compensated to some degree for a restriction in growth rate within this twelve week period. However, closer perusal of Davey's results showed that the apparent compensation came not from an increase in growth rate of the calves fed a lower level of milk, but from the check in growth rate caused by weaning, being more pronounced with those calves receiving the higher level of milk. This may have been brought about by the lower-fed calves being more adapted to their post-weaning diet; namely pasture. This would have meant that they were better able to increase their intake of pasture in response to weaning than the higher-fed calves which would have taken in less pasture prior to weaning.

It is unlikely that young calves receiving pasture can truely compensate for a period of under-nutrition early in life (assuming all calves, irrespective of rearing method, are equally adapted to the pasture diet). This is because Hodgson (1968) has demonstrated that over the period of age of three to six months, the voluntary intake of pasture by calves is controlled mainly by gut fill factors. This means that over this period the intake of the calf will be broadly related to the calf's live weight (Bines, 1970). Thus the lighter calves (representing the under-fed calves) will not be able to exhibit enhanced eating relative to those calves which are better fed initially. As enhanced eating following a period of under-nutrition is the main mechanism of compensatory growth (Allden, 1970), obviously the lighter calves will not be able to increase their growth rates relative to the heavier ones.

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APPENDIX I

Regression of energy content of oven-dried faeces (Y) on energy content of freezed-dried faeces (X)

a ± se	b ± se	r^2	sig. of b	Y ± se
0.048 ± 0.031	1.011 ± 0.089	0.899	$H_0: \beta = 0$	4.830±0.041
			$P < 0.1\%$	
			$H_A: \beta = 1$	
			$P > 50\%$	

Analysis demonstrated that the difference between the oven-dried and freeze-dried faecal samples energy content, was within the accuracy of the Bomb Calorimeter (±2%). This indicates that the difference in the DM% of a faecal sample when determined by these two methods, was due mainly to inadequate drying by the freeze-drying method and not to a loss of energy-yielding material with the oven-drying method.

In conclusion, no bias was introduced into the analysis by using the freeze-dried faecal samples for the energy determinations, while calculating the DM content with the results of the oven-dried samples.

APPENDIX II

Meteorelogical data

	May	June	July	August
Ground frost (days) 1972	5	19	11	16
30 year average	7.9	11.8	14.8	12.5
Rainfall (mm) 1972	110.9	39.4	101.4	77.7
30 year average	88.9	96.5	81.3	88.9
Temperature (°C) 1972	10.4	6.7	8.9	7.8
30 year average	11.0	8.0	8.0	9.0

The month of June had above normal ground frosts and below normal rainfall; a combination which led to a reduction in the growth rate of paddock 30 below expectation, over the period of the trial, necessitating the need to use other paddocks.

APPENDIX III

The use of one-day lag versus two-day lag in calculating apparent digestible energy of the two diets fed during period A2

Diet fed to		One-day lag	Two-day lag
Group C	DE(%) ± se	74.17±0.75	73.66±0.76
	CV(%)	4.52	4.61
Group P	DE(%) ± se	75.37±0.70	74.61±0.72
	CV(%)	4.15	4.32

APPENDIX IV

The effect of the age of the calf on the apparent digestible energy of the two diets fed during period A2

Analysis of variance

Source	d.f.	S.S.	M.S.	F.	Prob.of F
Periods(Age)	3	20.16	6.72	0.606	NS
Diets	1	14.47	14.47	1.305	NS
P x D	3	30.85	10.28	0.927	NS
Error	32	354.86	11.09		
Total	39	420.34	10.73		

APPENDIX V

(a) Calf and age effects on the apparent digestible energy of pasture fed during period A2

Analysis of variance

Source	d.f.	S.S.	M.S.	F.	Prob.of F
Periods(Age)	3	44.61	14.87	1.767	NS
Calf	4	39.37	9.84	1.169	NS
Error	12	101.00	8.42		
Total	19	184.98	9.73		

(b) Calf and age effects on the apparent digestible energy of concentrate diet fed during period A2

Analysis of variance

Source	d.f.	S.S.	M.S.	F.	Prob.of F
Periods(Age)	3	6.39	2.13	0.600	NS.
Calf	4	171.88	42.97	12.067	***
Error	12	42.62	3.55		
Total	19	220.89	11.62		

APPENDIX VI

Group mean daily DM intakes, averaged over weekly periods, of the calves during period A

Mean daily DM intakes (kg) of calves in	Age Period (weeks) 2	3	4	5	6	7	8	9	10	11	12
Group C	0.079	0.246	0.433	0.807	1.134	1.424	1.653	1.714	1.661	1.707	2.086
Group P	0.080	0.244	0.445	0.688	0.930	1.113	1.333	1.388	1.454	1.543	1.781
se of difference(±)	0.025	0.044	0.045	0.077	0.110	0.094	0.114	0.090	0.132	0.127	0.124
prob. of t_{12} (P%)			NS			**	*	**	NS	NS	*

APPENDIX VII

Group mean daily DM intake/kg$^{\frac{3}{4}}$ averaged over weekly periods, of calves during period A

Mean daily DM intake/kg$^{\frac{3}{4}}$ (kg/kg$^{\frac{3}{4}}$) of calves in	Age period (weeks)										
	2	3	4	5	6	7	8	9	10	11	12
Group C	5.02	14.90	24.80	43.62	58.23	69.20	75.84	74.77	69.74	69.75	82.47
Group P	5.32	15.25	26.33	38.96	50.90	59.15	68.37	68.76	70.37	73.50	82.50
se of difference ($\pm$)	1.63	2.58	2.77	4.47	5.36	4.68	5.03	3.78	6.03	5.51	4.87
Probability t_{12} (P%)	No significant results in this table										

APPENDIX VIII

Group mean live-weight of calves during period A

Mean live weights (kg) of calves in	Age of Calves (weeks) 1	2	3	4	5	6	7	8	9	10	11	12
Group C	39.0	40.8	43.7	47.5	50.8	54.4	58.6	63.0	67.3	70.0	72.2	76.3
Group P	36.4	38.1	41.3	45.1	47.3	49.0	51.2	53.8	55.8	57.5	58.7	61.5
se of difference(±)	1.4	1.3	1.5	1.5	2.0	1.5	1.2	1.7	1.6	1.4	1.4	1.4
Prob. of t_{12} (P%)	NS (weeks 1–5)					**	*** (weeks 7–12)					