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THE EFFECT OF MILK FEEDING LEVELS ON GROWTH RATES OF  
HIGH AND LOW BI FRIESIAN BULL CALVES BEFORE AND AFTER WEANING

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## ABSTRACT

Eight Friesian bull calves from high breeding index parents (HBI, BI of parents = 134) and eight from low breeding index parents (LBI, BI of parents = 103) were used to estimate the effects of milk intake and BI on calf growth performance, voluntary herbage intake, digestion and nitrogen metabolism.

1. The calves were allocated to one of two levels of milk intake from 3 weeks of age until weaning at about 7.5 weeks of age. The milk was fed twice daily at either 4.5 (LM) or 6.0 (HM) litres/calf/d.

2. Daily intakes of freshly harvested herbage (perennial ryegrass and white clover pasture) offered ad libitum throughout the pre-weaning period and for a further 3 weeks period following weaning, were measured.

3. The calves were then grazed on pasture together in a mob and the liveweight at 21-25 weeks of age was measured.

4. Calf growth rates at various stages were recorded. The HM calves grew significantly ( $p < 0.05$ ) faster than LM calves (0.55 v 0.44 Kg/d) in the pre-weaning period. Their growth rate was slower in the 3 weeks following weaning (0.21 v 0.31 Kg/d) but the difference in this period was not significant.

5. The overall growth rate from 3 to 21-25 weeks of age was not significantly different between HM and LM calves (0.52 v 0.53 Kg/d), nor was the calf LW at 21-25 weeks of age (124 v 130 Kg for HM and LM calves respectively).

6. LM calves consumed significantly ( $p < 0.01$ ) more herbage organic matter (OM) both before and after weaning (0.18 and 0.33 Kg OM/d pre-weaning and 1.13 and 1.28 Kg OM/d post-weaning for HM and LM calves respectively). Reducing daily milk intake by 1 Kg increased daily herbage OM intake by 0.11 Kg before weaning and by 0.12 Kg after weaning. The difference in herbage intake caused by milk intake level persisted for two weeks following weaning. It was not significantly different in the third week after weaning.

7. It was demonstrated that the LW at the commencement of the experiment (3 weeks of age) was positively correlated with the mean overall growth rate (from 3 to 21-25 weeks). LW at 3 weeks of age was

also positively correlated with the voluntary herbage intake in the third week following weaning, and also digestibility of herbage organic matter in the post-weaning period.

8. By extrapolating the linear relationship between nitrogen retention (NR) and nitrogen intake (NI) per metabolic weight ( $\text{Kg}^{0.75}$ ), the estimated nitrogen requirement for maintenance (Nm) was 0.418 g N/ $\text{Kg}^{0.75}$ /d.

9. There were no significant differences in growth rate, herbage voluntary intake, digestibility or nitrogen metabolism between the BI groups, nor any interactions between the BI and levels of milk intake.

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## INTRODUCTION

It has been shown in the 1950's in NEW ZEALAND that herbage of high quality is an acceptable solid feed for young ruminants (McMeekan, 1954a,b). McArthur (1957) and Preston et al (1957) also showed that calves at 4 - 5 weeks of age can digest grass as efficiently as adult ruminants. Calves of eight weeks old can digest pasture as effectively as they digest concentrates (Byford, 1974). However, the amounts of herbage ingested by the young calves, no matter how high the herbage quality, do not ensure high growth performance. This has been shown in Byford's work (1974) with early weaned Friesian calves. It is acknowledged that the intake ability is the main limitation to the efficient use of herbage by the young calf (Roy, 1980). The intake of solid feed of young ruminants may be controlled in a far more complex way than that of adult ruminants. Hodgson demonstrated in his work (1971c) that the intake of solid feed of young ruminants was mainly limited by some behavioural factors. It is generally agreed that the effect of milk intake level upon calf solid feed intake is most important. The solid feed intake in young calves is depressed by high milk feeding level. But on the other hand, the calf growth performance is positively correlated to the milk intake level. Therefore, encouraging calves to eat more solid feed is always accompanied by a lower growth rate (Le Du et al. 1976a). Work with beef cattle has suggested that the growth rate in the first 3 - 4 weeks of life is important for later growth performance whereas the growth rate after that stage is less important, in terms of its direct effect on later growth rate (Davey, 1974).

Recent work at Massey and in Ruakura showed that HBI Friesian and Jersey cows eat slightly more per unit of metabolic weight than LBI cows (Davey et al., 1983, Bryant, 1983) whereas there is no similar work on HBI and LBI calves reported.

The objectives of the present experiment were to observe the effects of milk feeding level upon:

1. the intake of herbage and herbage intake development of HBI and LBI Friesian calves from 3 weeks of age,
2. the calves growth rates in the pre- and the post-weaning period until they reached about 24 weeks of age,

Another objective was to observe the effect of BI on calf growth rate, herbage intake, and digestibility at different milk feeding levels.

The review of literature is started with a brief outline of the anatomical and physiological development of the alimentary tract, especially reticulo-rumen of the young calves. This section describes the effect of solid feed intake upon the development of the reticulo-rumen and rumen papillation and the establishment of the rumen microflora. The effect of inoculation of the young ruminant's rumen with adult ruminant rumen liquor is discussed. In the following section, the development of solid feed intake of young ruminants is described. Emphasis is put on 1) the mechanisms of the voluntary feed intake, especially solid feed intake of young calves, and 2) the factors, of environmental, feed, and genetical origins, which influence the solid feed intake of the calves. Attempts are made to relate the different feed intake mechanisms to each other.

Then the digestion of main nutrients, carbohydrates, protein and lipid, etc., by pre-ruminant and ruminant calves is described. Attention is also paid to the effect of milk feeding on solid feed digestion in reticulo-rumen. Nutrient requirements of the calves and the way of estimating these requirements are briefly discussed. Some of the estimates are presented in the fourth section. In the final section, the knowledge of calf intake, digestion and requirements for nutrients (reviewed in the above sections), are combined and discussed with a brief review of some popular calf rearing systems.

## CHAPTER 1

### LITERATURE REVIEW

#### 1.1. ANATOMICAL AND PHYSIOLOGICAL DEVELOPMENT OF THE ALIMENTARY TRACT OF YOUNG CALVES

New born calves can only digest liquid feeds, preferably colostrum and whole milk. At birth, the forestomach of calves, the reticulo-rumen and the omasum, is not fully developed and functional. The anatomical and physiological development of the forestomach, especially the reticulo-rumen, in early life determines the change of calf digestion from a monogastric to a ruminant pattern. Such development is accompanied and promoted strongly by the development of solid feed intake and digestion.

##### 1.1.1 Rumen Development

The rumen is the organ where fermentation of the ingested feed occurs in adult ruminants. It has three important functions in this process, (1) accommodating the large amount of feed ingested, (2) providing suitable conditions for rumen microbial flora establishment, habitation and function and (3) ruminating. Rumen development in calves is actually the development of these functions. Because the size of the rumen is very small at birth, either absolutely or relatively the enlargement of reticulo-rumen is necessary for the intake of large quantity of solid feed in young calves. At birth, rumen takes about 30% of the total stomach volume compared with 87% in adult cows. The size of rumen appears to be closely related to the amount of solid feed that can be ingested in adult ruminants (Campling, 1970). Although there are other limiting factors influencing solid feed intake in a calf's early life, it is also a possible factor controlling solid feed intake in the young ruminant.

The development of the reticulo-rumen and other parts of the stomach is very dramatic during the first 6 mths of life (Table 1.1).

Table 1.1 Percentage of Bovine Stomach Tissue Contributed  
by Each Compartment(%)

COMPARTMENT	AGE (WEEKS)						
	0	4	8	12	16	20-26	34-38
RETICULO-RUMEN	38	52	60	67	64	64	64
OMASUM	13	12	13	14	18	22	25
ABOMASUM	49	36	27	22	15	14	11

from: Warner & Flatt (1965, cited from Church, 1972)

Table 1.2 The Effect of Whole Milk Feeding Level on Stomach  
Development of Calves Slaughtered at 12 Weeks of Age

LEVEL OF FEEDING (% OF LW)	TOTAL STOMACH WEIGHT(g)	RETICULO- RUMEN(%)	OMASUM (%)	ABOMASUM (%)
8	1821	64.1	16.9	18.9
10	1871	62.8	17.4	19.8
12	1833	60.6	15.4	24.0
14	1651	56.9	14.4	28.7

The feeds fed and feeding regime largely determine the rate of stomach development, especially reticulo-rumen development. It is generally agreed that solid feed encourages the growth of reticulo-rumen while high level of liquid feeding slows the development of reticulo-rumen and whole stomach. Kaiser's work (1976) clearly showed the effect of milk feeding level on total stomach weight and contribution by each compartment (Table 1.2). The reticulo-rumen of the calves under low milk feeding levels (milk allowance: 8 and 10% of liveweight(LW)) was significantly larger than

that of those under high milk feeding level (12 and 14% of LW). Relative growth rate of abomasum was higher under high milk treatments (12% and 14% of LW).

#### 1.1.2 Rumen Papillary Development

The rumen wall of the new born calves has quite small (1mm in height) papillae (finger-like projections). The papillae increase the surface area of the rumen wall and thus the area through which nutrients, mainly volatile fatty acids (VFAs), can be absorbed. Some work also showed that papillae may be able to excrete amino acids and influence the nitrogen metabolism in the rumen (Boila & Milligan, 1980). The papillary development under normal conditions is closely related to rumen function. It is responsive to the intake of solid feed and consequently the presence and concentrations of VFAs in the rumen (Khouri, 1966). The papillae reached complete development at 7-8 weeks age if solid feed was fed (Tamate *et al.*, 1962). But the development of rumen papillae is much greater in concentrate fed calves than in those given large amounts of hay and other roughages (Brownlee, 1956). This may be due to the larger amount of VFAs produced after ingestion of concentrates compared with roughage ingestion.

#### 1.1.3 The Establishment of Rumen Microflora

The full function of the rumen is eventually dependent upon the final establishment of a normal population of rumen microflora. Most of the organic matter ingested by ruminants is digested in rumen by microorganisms (section 3.2 ). New born calves hardly have any rumen microorganisms. Compared with adult ruminants , whose rumen provides quite favourable environment for microbial growth (Church, 1969), the low pH value of calf rumen is probably the main limiting factor for microbial flora development (Roy, 1980). A complete ciliate microfauna become properly established as rumen pH is stablized near neutrality (pH >6) at about 8 weeks of age (Mann *et al.*, 1954).

The solid feed intake may be another factor exerting influence on the establishment of rumen microflora. First, the ingestion of solid feed may bring microorganisms or their spores into rumen. Pasture and hay are quite likely to be the media of microorganism transfer between adult ruminants and calves in farm situation. Second, solid feed in the rumen supplies energy and protein and other nutrients for rumen microorganisms. Third, the kind of solid feed ingested may have an effect on the nature of the organisms which dwell in the rumen. Pounden & Hibbs (1948b) found the growth and predominance of an organism seemed to depend, to a large extent, upon the substrate present in rumen. As this substrate changes with changes of diet, so does the type of organism that predominates.

The effect of inoculation on the establishment of the rumen microflora or the growth rate of the calves seems not constant. According to some early work, rumen bacteria are not likely to be transferred from adults to young calves in the form of spores because of the short survival time of the spores (Bryant, 1959). In this view, oral contact or inhalation of organisms temporarily suspended in the air is the possible natural way of inoculation and artificial inoculation appears necessary, or at least beneficial, for the adequate development of rumen microflora in early age. But in fact, isolation of calves from adult ruminants immediately after birth did not prevent the establishment of some typical rumen bacteria in calf rumen. On the other hand, however, the isolated calves generally had lower levels of cellulolytic organisms (Bryant & Small, 1960). Contact with adult ruminants appears to be necessary for protozoa establishment (Bryant et al., 1958. Borhami et al., 1967. Ziolechi & Brigg, 1962). High intake of milk or grain tends to inhibit development of a ciliate population, presumably due to low rumen pH (Pounden & Hibbs, 1948a). This may be the cause of lower cellulose digestion under liberal milk feeding (Lengemann & Allen, 1959).

In general, it appears that the calves can eventually develop their normal microflora without assistance as long as they have free access to roughage or pasture. The bacteria appear earlier than protozoa in rumen (Singh et al., 1983). So, inoculation would have a bigger effect on development of a protozoa population in the rumen as

Bryant & Small (1956) observed. The fact that inoculation has different and inconsistent results may be partly due to the effect of diet. For highly digestible concentrates or young pasture inoculation may not be so useful.

The backflow of milk from abomasum may bring lactobacilli to rumen from abomasum and inoculate it (Roy, 1980) whereas its effect on the establishment of rumen microflora is doubtful. Schwab *et al.* (1980) found that feeding a nonviable *Lactobacillus bulgaricus* fermentation product to calves beginning at 2 to 9 days of age may improve weight gains and ad libitum feed consumption, particularly during the pre-weaning period. He suggests that the effect is likely to be in the small intestine instead of on rumen fermentation because the effect was not significant after the calves were weaned. Lowlar and Kealy (1971) observed in artificially reared lambs that the escaping of milk into rumen was one of the causes of low rumen pH and this was related to the low dry food digestibility and a poor establishment of rumen microflora.

#### 1.1.4 The Changes in the Abomasum and the Intestine

In preruminant calves, the abomasum and small intestine play the dominant role in digestion. Their function continues to be necessary after the forestomach is fully developed. They keep on growing after birth. But their relative size and weight, like their importance in digestion, decline as the calf grows. So in adults, the abomasum occupies only about 8 % of the total capacity of the stomach (Getty, 1975). The development of the abomasum is largely determined by the milk intake level. It has been shown that the development of the abomasum was slowed by the decrease in milk intake (Kaiser, 1976).

Work with sheep (Wardrop & Commbe, 1960) showed that the relative weight of the intestine decreased at 4 wks, 8 wks of age and maturity respectively. The relative capacity of intestine in the whole gastro-intestinal tract also declines as the animals grow. The capacity of intestine was 72.5, 67.4 and 50.9 % of that of the gastro-intestinal tract at 4 wks, 8 wks of age and maturity respectively.



## 1.2 DEVELOPMENT OF SOLID FEED INTAKE OF YOUNG CALVES

Calves are instinctively able to ingest and digest milk or adequate milk substitutes. In contrast, the voluntary intake and digestion of solid feed has yet to develop in the early stages of their life. In fact, because of the relationship between solid feed intake and rumen development (Hodgson, 1971b), the early voluntary solid feed consumption influences the potential feed intake after weaning. This has been shown by many experiments and farming experience. Due to the differences in their nutritive and physical properties, the consumption of liquid feed and solid feed is very different. The calves generally can eat more liquid feed than solid feed in terms of dry matter (DM) before they reach 70 kg LW. Until they reach 100 kg LW calves cannot ingest more digestible energy (DE) from solid feed than from liquid feed (Roy, 1980). In other words, they cannot grow faster than liquid fed calves before they reach at least 100 Kg LW. There usually is a period of time during which the diet of the calves gradually changes from liquid feed to liquid plus solid feed, then to solid feed only (weaning). Since there is obvious economical advantage in feeding solid feed if the expected growth rate can be achieved, encouraging calves to eat more solid feed at an early age, shortening the period during which calves eat liquid feed, is always one of the main topics in calf nutrition research. This also reduces the labour cost for calf rearing which is another consideration in calf rearing. Since the voluntary solid feed intake is largely limited, especially for young calves, the decrease of liquid feed intake cannot be fully compensated by the increased solid feed intake. Consequently, in the case where high growth rate is required, like in veal production, it is less important to use solid feed. On the other hand, for the herd replacement calf rearing, early weaning encourages them to eat solid feed earlier in a larger amount than calves fed liquid feed and is a practical method.

### 1.2.1 The Mechanisms of Solid Feed Intake Control in Young Calves

It is well known that differences in voluntary intake exist between liquid feed and solid feed, and between the various solid feeds with different properties and probably between animals due to genetic differences.

Questions naturally arising from these phenomenon are

1. What is(are) the mechanism(s) controlling feed intake especially solid feed intake in young ruminants?
2. How do they develop?
3. How are they related to each other?
4. What factors influence voluntary feed intake of calves of different ages?

The first three questions will be discussed in this section while the factors influencing voluntary solid feed intake will be considered in next section (section 1.2.2).

The mechanisms of feed intake regulation in ruminants and factors influencing feed intake have been intensively reviewed by many workers (e.g. Campling, 1970, Bines, 1976, Journet & Romond, 1976, Meijs, 1981). Roy (1980) reviewed the feed intake regulation in calves.

Several mechanisms have been proposed. It appears that the theories of metabolic and physical mechanisms are well established. They are mainly based on genetic capacity in using the nutrients absorbed and the physical capacity of alimentary tract in accommodating bulky feed. For grazing animals, the complication of the grazing process makes the grazing skill or grazing behaviour another possible way of limiting feed intake. While for young ruminants, the oropharyngeal factors associated with the development of eating behaviour may control the initial development of solid feed intake (Hodgson, 1971d).

The nervous system, more probably the hypothalamus, appears to play an important role in the control of feed intake. This has been demonstrated with the increased intake after electrical and chemical stimulation of the lateral hypothalamus in sheep and goats (Meijs, 1981). Physiologically, the hypothalamus may be sensitive to changes in hormone levels, some blood metabolite concentrations and nervous

signals. But whether or not the hypothalamus plays the dominant role in the normal animal, in balancing and integrating signals from various parts of the body, remains open to question (Morrison, 1977).

#### 1.2.1.1 The Metabolic Control

The metabolic control results from some signals, such as the changes during a meal of the plasma concentration of metabolites arising from digestion and absorption, the changes of body temperature, circulating hormones, the size of the fat reserves in the body etc.. Basically, the metabolic mechanism of feed intake is to keep the balance of input and output of nutrients, particularly energy. The above mentioned signals are all related to the energy status of the animals in either short term or long term, directly or indirectly. The following mechanisms may be involved.

##### (1) Chemostatic mechanisms

This is considered to be the main regulation system for short term control. The balance between energy input and output for ATP production, protein and fat synthesis is likely to keep the plasma concentrations of some key metabolites constant. Satiety may result from the increase in such metabolite concentrations. The nature of such metabolites is far from clear in ruminants though glucose is found to be the main signal in monogastric animals. For preruminant calves, this may apply because glucose is also the main energy supplying material and their blood sugar level changes with feed ingestion and digestion. But this may not last long since calf blood sugar level decreases and concentrations of organic acids increase as the calves grow. Such change is completed at about 6 to 7 wks of age (Huber, 1969, McCarthy & Kesler, 1956). So, if glucose is the regulating metabolite for preruminant calves, it would be important only for the first few weeks of life. VFAs thereafter play an increasingly important role in energy supply. But the evidence that VFAs are the signal in ruminants is not well established. Reasons for this may be 1) VFAs are a group of compounds, the ratio of the three

main acids varying with the feed, 2) VFAs production rate in the rumen varies with the diets. Concentrates are fermented much faster than herbage even with the same digestibility.

## (2) Lipostatic mechanisms

It seems that the above mentioned signals would not be sufficient to maintain long-term stability in energy balance that is commonly observed in adult animals, and the size of the fat reserves in the body might provide the best indicator of energy status of the animals. The levels of blood free fatty acids resulting from adipose tissue metabolism may serve as a signal for the regulation. But some evidence has shown that such long-term regulation system is not perfect. For example, Kanarek and Hirsch (1977) have shown that normal animals offered highly palatable diets will slightly but consistently exceed their predicted intake of energy and eventually become obese.

## (3) Thermostatic mechanisms

This theory is based on the existence of temperature sensitive centres in the hypothalamus. However, under normal physiological conditions in ruminants this effect seems unimportant (Rohr 1977 cited from Meijs, 1981). On the other hand, environmental temperature may have an effect on feed intake by this mechanism as a means of adjusting the energy balance. In a cold environment the feed intake increased whereas hot climate depressed intake (Jones, 1972, Baile & Forbes, 1974, Bines, 1976). It is doubtful, however, that the normal changes of temperature in temperate areas, can cause marked difference in intake. One experiment in a temperate area showed no relationship between grazing time and air temperature over a wide temperature range (Jamieson, cited from Meijs, 1981).

### 1.2.1.2 The Physical Control

Ruminants fed low quality bulk feeds usually can not achieve a high intake level . Consequently they fail to fulfil their production potential (Bines, 1971). Obviously, the voluntary feed intake in such a situation is not likely to be controlled by metabolic requirement. The capacity of the alimentary tract, especially the reticulo-rumen and abdominal capacity may set a limitation on the animal's ability to ingest in this situation.

Since feed ingestion, digestion and residual excretion are dynamic processes , therefore, besides the absolute capacity of the alimentary tract, the passage rate of digesta and the concentration of DM in the rumen content also have influence on voluntary feed consumption over a prolonged period of time (Hodgson, 1971b,e). The high passage rate of digesta is quite likely to be the result of high intake. But the factors influencing the dry matter content of digesta in reticulo-rumen are not well understood.

#### (1) The capacity of the alimentary tract

This parameter and other similar but not necessarily equivalent parameters, like rumen fluid volume, weight of alimentary tract, the digesta weight in the alimentary tract etc. are more or less associated with solid feed intake (Hodgson, 1971c, Meijs, 1981).

The effect of rumen size on feed intake can also be shown by oral intake changes after the rumen content is artificially changed. Hodgson (1971d) showed that removal of digesta from the rumen increased solid food intake.

#### (2) The rate of digesta passage

The rate of digesta passage rate through the alimentary tract, especially the retention time in rumen determines the amount of solid feed that can be accommodated in a period of time. This is probably more significant for grazing ruminants which ingest their diet over a prolonged period.

The disappearance rate of digesta from the rumen is primarily dependent upon the rate of feed particles breaking down to a certain size. Such a breaking-down process can be either chemical or physical.

Feed digestibility represents the rate of chemical break-down. It is known that the intake of grazing animals increases with organic matter digestibility over the range from 50 to 80 % (Hodgson, 1975). For concentrates, the voluntary intake increases until the digestibility reaches about 60% (Dinius and Baumgardt, 1970). Such an increase in intake is likely due to the increased passage rate instead of increased reticulo-rumen fill. It is observed that animals offered dried grass with digestibility varying from 50 to 70 % have a similar reticulo-rumen fill at the end of the meal (Meijs, 1981). Alam et al.'s work with lambs and kids also showed that the higher intake of lucerne hay compared with meadow hay was associated with shorter retention time in the rumen.

The physical break down is carried out through the ruminating process. It interacts with the chemical break down. It is observed that leaf fractions and stem fractions of grass with similar digestibilities have very different voluntary intakes because of their different retention time. The retention time is much longer for stem than for leaf fractions (Poppi et al., 1981a, b). Further study showed that short retention time in the rumen of the leaf fraction was associated with an apparent high rate of digestion of neutral detergent fibre (NDF) and its high rate of passage from the rumen (Poppi et al., 1981b). Interestingly, their study also showed that the retention time of the small particles (<1.18mm) has the most important influence on total dry matter retention time instead of the large ones (>1.18mm). This is in disagreement with the general idea that the break down of large particle is important in determining the retention time.

#### 1.2.1.3 Behavioural Control

Animals have to make an effort to ingest feed offered to them and swallow the feed ingested. Therefore, it is possible that the

animal's ability to make such effort, which is likely to be limited by some physiological, physical and behavioural factors in some situations, like grazing, influences feed intake.

Such effort is probably negligible for mature animals fed mainly concentrates in non-diluted condition. But for the grazing animal, it may erect a limitation on voluntary intake depending upon the grazing management. Calves are not skilful grazers. In addition to this undeveloped salivary glands may have further effects on mastication and swallowing. So they are more likely to be limited by so called oropharyngeal factors. The most relevant evidence that suggests behavioural control in young ruminants is from Hodgson's work (1971d). He found that the addition of feed material to the rumen resulted in a depression in the intake of dry matter (DMI) which was greater than the increase in DMI following the removal of digesta. This suggests that the young ruminants are unwilling to eat extra solid food even if the metabolic and physical barrier on intake is removed. The behavioural control of solid feed intake in young ruminants is also shown by the long term effect of early experience on solid feed intake later. Merino lambs which were initially (at 5 to 20 days of age) given wheat ate significantly more wheat at 6, 12, 24 and even 34 months of age (Green et al., 1984).

Some research work showed that artificially reared piglets have a strong tendency to suck anything since their desire of sucking is not easily satisfied by even rubber teats (Stephens, 1982). Such abnormal behaviour may quite likely affect dry feed ingesting behaviour though this aspect is not included in the work.

#### (1) Prehending and ingesting

In the grazing situation, the intake of grazing animal can be considered as the product of bite size, biting rate and grazing time, expressed as following equation:

$$\text{DMI (kg/d)} = \text{Bite size(g/bite)} \times \text{Biting rate(Bites/min)} \\ \times \text{Grazing time(min/d)/1000}$$

Under poor pasture conditions, the decreased intake is often due

to the decreased bite size in adult ruminants (Stobbs, 1973a, b). For indoor fed calves, it has also been observed that the time spent on consuming per unit untreated dried herbage was much longer than that on pelleted feed (0.24min/g DMI vs 0.06-0.07 min/g DMI) (Hodgson, 1971a). A similar result was obtained in the comparison of concentrate and pasture in feeding early weaning calves (Byford, 1974). Such difference in eating rate, more probably due to the smaller bite size rather than slower biting rate, may be attributed to the following reasons:

1. the large difference in bulk density between the solid feeds in question (Byford, 1974, Hodgson, 1971a). So, the intake per mouthful is limited;
2. the possible upper limit on the secretion of salivary juice per unit of time.

## (2) Mastication and swallowing

The mastication and swallowing of the solid feed ingested require muscular work of the jaw as well as the secretions of salivary gland as an aid for moistening. In adult ruminants, the fatigue of the jaw muscle is not considered as a limiting factor in feed intake. But this is not confirmed in calves. It is known that the calf's salivary gland, like the rumen, is not fully developed at birth. According to the study with lambs and kids, rate of salivary flow was significantly correlated to the fresh weight of the rumen but not to body weight (Church, 1969). So it may be assumed that young ruminants will have problems in masticating and swallowing solid feed first rather than accommodating the solid feed ingested by reticulo-rumen. Kellaway et al. (1973b) have shown that exhaustion of the salivary gland was an important factor in influencing the intake of early-weaned ruminants. Recently, work in UK also showed that feed intake, primarily roughage, is suppressed when water and electrolytes are in deficit (Doris & Bell, 1983).

Since eating and ruminating pelleted feed take much shorter time than long roughage and the production rate of saliva during eating and ruminating is higher (Kellaway et al., 1973a), the total production of



salivary juice on a pelleted ration or concentrates is likely to be considerably lower or more DM could be ingested without the exhaustion of salivary juice.

The response to the addition of sweetening agents to the rations appears to be greater in the young ruminants than in older ruminants (Preston, 1956). Early weaned calves ate 11 to 16% more feed that was supplemented by molasses than they ate of non-molasses supplemented feed. This tends to suggest the greater importance of behavioural or opharyngeal factors in the control of solid food intake in young ruminants. It may be associated with its stimuli on the secretion of salivary juice or merely because it is more acceptable. It is shown that human infants have an instinctive ability to taste some flavours, accepting sugar solution but rejecting quinine solution (Bolles, 1983).

1.2.1.4 The Relationship between Different Mechanisms

It is acknowledged that the mechanisms whereby the intake of food by ruminants is regulated are highly complex and their effects are not clear-cut. A general relation between metabolic control and physical control has been summarized in a model proposed by Montgomery & Baumgardt (1965) (see Fig. 1.1).

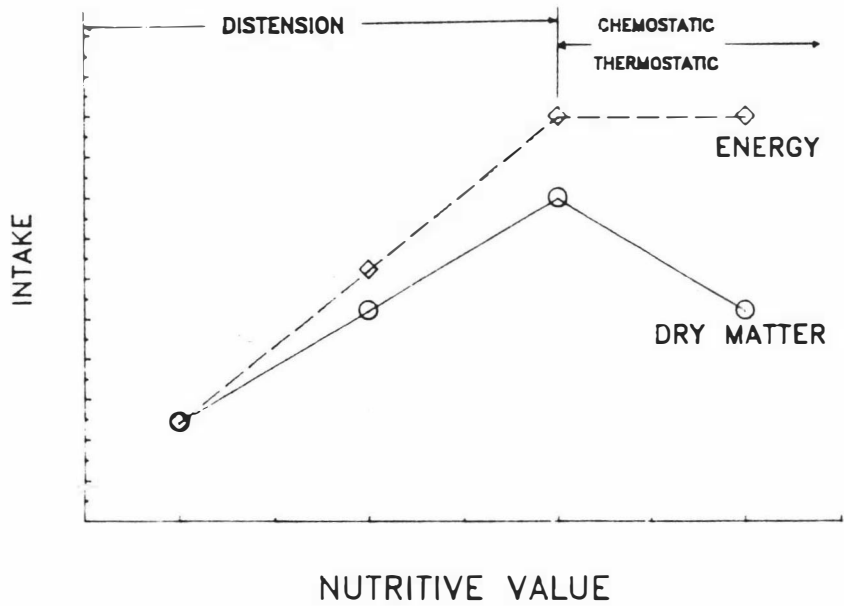


FIG. 1.1 Probable Relationship between Energy and Food Intake  
Controlling Mechanisms

The shortcomings of this model are:

1. It separates the control of two mechanisms sharply, but in fact there may be a transferring stage when both mechanisms function. They may also have an effect on each other.

The intake is not constant even with a low nutritive value feed. It is shown that the intake of pasture per unit weight varies with the production potential of the animal with the digestibility of herbage as low as 67.3 % (Curran & Holmes, 1970, Hodgson, 1975). In fact, the nutrient deficit (potential minus actual intake) to which the animal is subjected may to some extent adjust the intake limitation exerted by physical control or other control mechanism other than metabolic mechanism (Hodgson, 1975). The fact that milk feeding level strongly influences the solid food intake give support to this proposal.

2. For young ruminants, the possible behavioural control has not been considered in this model. The nutritive value, expressed as digestibility, is not the only factor influencing intake, the physical form of the feed may be more important (Hodgson, 1971a).

3. The rumen fermentation characteristics of the feed are also ignored. Such characteristics have been shown to influence intake ability. The typical example in adult ruminants is the difference in pasture and concentrate dominant diet intake (Fig. 1.2).

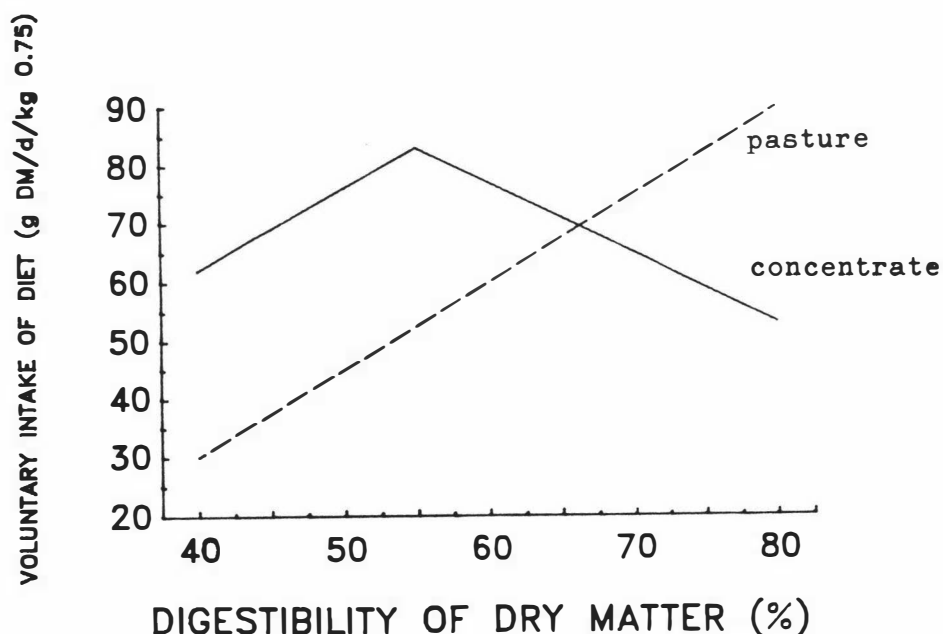


FIG. 1.2 Comparison of Two Relationships between Voluntary Intake and Digestibility (Dinius & Baumgardt, 1970, Troelsen & Campbell, 1969)

In calves, some indirect evidence also suggests that low rumen pH may have an effect on voluntary solid feed intake (Kellaway et al., 1973a, b) though the low salivary flow rate of young ruminants may be one of the causes since its buffering ability from salivary juice is small.

### 1.2.2 Some Factors Affecting Solid Feed Intake of Young Calves

Encouraging calves to eat more solid feed at an early age has the advantages of decreasing rearing cost and the stress caused by weaning, i.e. weaning checks. In practice, voluntary solid feed intake of calves differs widely due to many reasons. Below are some of the important ones.

#### 1.2.2.1 The Level of Milk Feeding

For many reasons, colostrum and a certain amount of whole milk or adequate milk substitutes are a necessity for successful calf rearing.

Calf health and minimum mortality are always considered by farmers to be as important as rearing cost. The amount of liquid feed fed is often associated with the growth rate that can be achieved (Kaiser, 1976), so it varies with situations where different growth rates are required.

Many experimenters have shown that there is a close negative correlation between the level of liquid feeding and solid feed intake before weaning and for a period after weaning (Hodgson, 1971e, Leaver & Yarrow, 1972, Baker et al., 1976, Le Du et al., 1976a,b, Baker and Barker, 1977, Le Du and Baker, 1979, Penning and Gibb, 1979). The regression of voluntary solid feed intake on the allowance of milk substitute before and after weaning was shown to be significant ( $r$  ranging from 0.24 to 0.64) (Hodgson, 1971c). LW at birth seems to be a notable factor. Walker and Hunt (1981) showed that the response of young ruminants to restriction of milk allowance to maintenance level varies with their birth weights. The restriction resulted in no increase in intake of pelleted feed both before and after weaning for lighter lambs (birth weight < 3.2 kg), but for heavier lambs (birth

weight > 3.6 kg), it resulted in significantly more pellet intake. It may be the interaction of metabolic regulation-lipostatic mechanism and other control mechanisms. Similarly, Leaver and Yarrow (1972) demonstrated a positive relationship between birth weight and concentrate consumption by calves. But in their experiment, a constant milk allowance was fed over a range of weight, resulting in the heavier calves being possibly underfed and therefore caused high solid feed consumption. On the other hand, some work suggested that birth weight had no effect on solid feed intake. Kay (1969) examined records of 150 Friesian bull calves, birth weight of which ranged between 33 and 48 kg and found no effect of birth weight on the growth of these calves from weaning to 100 kg live weight. It is assumed, however, that comparable growth rate implies comparable intake of solid feed. But Adeneye (1982) showed with five breeds (Friesian, Holstein, Holstein X Friesian, Jersey and Brown Swiss) that the birth weight exerted a highly significant influence ( $p < 0.01$ ) on later body weights (measured until 16 weeks of age).

#### 1.2.2.2 The Properties of Solid Feed

Based upon the hypothesis of behavioural control and/or physical control of solid food intake, the physical and nutritive properties of the solid feed offered to the calves will, to a large extent, determine the voluntary solid food intake of young ruminants provided the influence of milk feeding level is not considered.

The solid feeds used in most situations can be classified into the following three classes:

1. Concentrates -- meals or whole grains;
2. Pasture -- either grazing or freshly cut;
3. Hay and silage.

Furthermore, grinding and pelleting can largely change some physical properties of the feed. So pelleted feed, compared with unpelleted one, has some unique properties.

The differences between the feeds mentioned above lies mainly in the following aspects: bulk density, digestibility and energy content per unit wet weight (Table 1.3).

## (1) Concentrates

Concentrates are usually characterized by high digestibility, high bulk density and high ME content. Consumption of concentrates is usually higher than pasture or hay in young ruminants. Byford (1974) showed that concentrate was a better early-weaning food for calves primarily due to its high voluntary consumption. The intake of herbage decreased with the increase of meal offered over 5 to 11 weeks of age (Poole, 1977).

However, such preference appears to decline as the calves grow. Castle & Walker (1959) found no advantage in growth rate by supplementing calves on pasture from 8 to 20 weeks of age. Work in Canada also showed that if good quality pasture is available, supplementing concentrate does not increase live weight gain after 8 weeks of age (Gorrill, 1967). This may suggest that the solid feed intake of calves after approximately 8 weeks of age is less likely to be controlled or limited by the physical mechanism provided good quality pasture is offered. The solid feed intake is increased when concentrates are offered to calves consuming low quality roughage (Leaver, 1973, Poole, 1977).

Probably due to the improved rumen fermentation, the calves fed concentrate incorporating a certain amount of roughage eat more solid feed than those offered concentrate only (Johnson & Elliott, 1969, Owen et al., 1969, Strozinski & Chandler, 1971, Weston, 1979, Thomas & Hinks, 1983). The highest solid feed intake occurred at roughage concentrations ranging from 15 to 67.5% depending upon the quality and processing of the roughage.

But it is found that feeding concentrate and roughage separately did not increase the total solid feed intake, probably due to the calf's unwillingness to eat roughage. Weston (1979) observed that increases in straw content from 2 to 14% were accompanied by the increases in 1) the rate of flow from rumen of digesta, sodium and potassium, 2) the pH of ruminal contents and 3) the time spent on ruminating though the digestibility was actually decreased. It is not clear which factor was responsible for the increased voluntary feed

intake . The increased rumen pH was also observed in lambs fed whole barley compared with those fed ground barley (L'Estrange, 1979).

## (2) Pasture and its characteristics

Herbage of high quality has long been shown an acceptable solid feed for young ruminants. Such pasture is often characterized as being short and leafy. It may have ME content ranging from 11.5 - 12.0 MJME/kg DM. But due to the low DM content (about 15%), the energy content per unit wet weight is low, approximately 1.73 to 1.80 MJME per Kg fresh herbage. Furthermore, such pasture would have a crude protein content of about 19% or even higher (Corbett, 1969).

Work in New Zealand in 1950's demonstrated that calves could be put on pasture of excellent quality as early as 1 - 2 weeks of age and spring born calves could be successfully reared outdoors (McMeekan, 1954a, b). McArthur (1957) and Preston et al. (1957) in New Zealand also showed that calves at 4-5 weeks of age can digest grass as efficiently as adult ruminants. Calves of eight weeks of age can digest pasture as effectively as they digest concentrate (Byford, 1974). However, the amount of grass ingested by young calves does not always ensure satisfactory growth performance. In other words, the intake of pasture is the main limitation in pasture utilization by calves in early age (Byford, 1974).

For grazing calves, besides the usual problems related to the properties of the solid feed, the grazing management and environment also have an obvious effect on herbage intake.

Most workers have found that weight gain decreased as the time of year at which calves were born and put outside advanced from spring to mid-summer. the decline of pasture quality may be the main reason for this.

Young calves are thought to be extremely selective grazers probably due to their behavioural factors. For example, Friesian weaners (aged 2 months) could select a diet of 96.5% leaf with N content as high as 25.8 g/KgDM from the pasture with 7.3 to 19.3 g N/KgDM (Moss & Murray, 1984). Under low herbage allowance they would sacrifice the quantity in order to select high quality herbage. So a

generous herbage allowance is usually suggested. Roy (1980) proposed that the calves should be moved to a fresh paddock after the grazing height of the sward declines to below 8cm, as otherwise intake of grass will fall. An experiment in UK showed that herbage intake was reduced by about 18 % as daily herbage allowance of 4-9 months calves was reduced from 90 to 30 gDM/kg LW (Jamieson & Hodgson, 1979). In contrast to this, Baker and Barker (1977) showed that the calves of approximately 58 up to 95 days of age had similar herbage organic matter intake at herbage allowances of 20, 40, 60 and 80 g OM/kg LW respectively. Thereafter, herbage intake was depressed by 20g OM/kg LW allowance. But in their experiment, the post-grazing height of the sward was always higher than 9.7cm, above that suggested by Roy (1980). This suggested that the intake of herbage of their calves might be very small at all herbage allowances probably due high milk intake.

Table 1.3 Comparison of Some Characteristics  
of Concentrate, Pasture and Hay

FEEDS	DM%	MJDE/KgDM	MJDE/KgFW*	MJGE/KgDM
CONCENTRATES	91.2%	14.3	13.0	19.2
PASTURE(SPRING)	15.0%	13.9	2.1	18.4
HAY	89.5%	-	-	17.7

\* FW: Fresh weight

From: Corbett (1969), Hodgson (1971a), Byford (1974).

Pasture characteristics, especially height, density and herbage mass have been demonstrated to have an influence on herbage intake of both adult ruminants (Hodgson, 1975, Meijs, 1981, Stobbs, 1973a,b) and calves (Hodgson *et al.*, 1977). This can be explained mainly by grazing behaviour.

### (3) Hay and silage

Hay and silage are rarely used as a sole solid feed for young

ruminants because of their low quality . Hay can be utilized together with concentrates so the total solid feed intake is increased (see above section). Calves have been reared entirely on high-protein lucerne hay from 8 weeks of age, but growth rate was somewhat subnormal (no exact growth rate was mentioned) (Roy, 1980).

Hay may have a bigger effect on the development of the reticulo-rumen since it exerts stronger physical stimulation on the rumen walls. It also has an effect on salivary gland development through its mechanical stimulation (Church, 1969). The comparison of hay and silage as feed for store lambs (starting weight 28-29 kg) showed that the quality of hay had a significant positive effect on its consumption whereas the quality of silage (DDM 62.2%) had a negative effect on intake (Sheeham & Fitzgerald, 1977). This is likely to be related to the fermentation in rumen and pH of the feed. Also, voluntary intake of silage may be less than that of hay made from the same crop (Harris & Raymond, 1963, Murdoch, 1964).

#### (4) The digestibility of solid feed

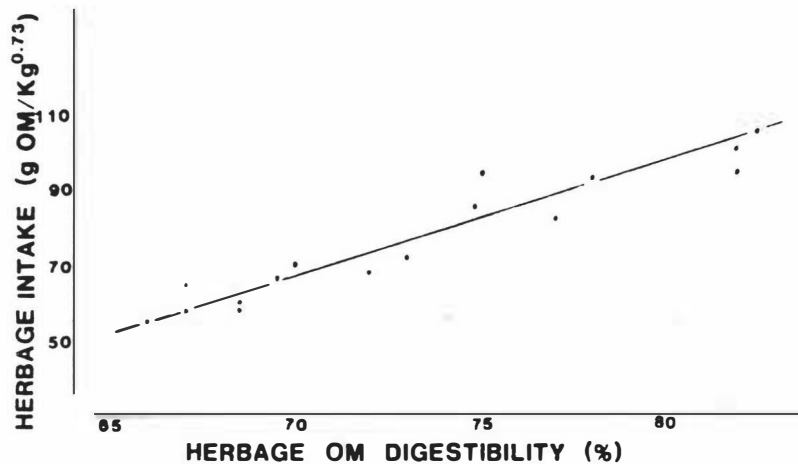


FIG. 1.3 The Relationship between Herbage OM Digestibility(%) and Digestibility(%) and OM Intake (g/kgLW<sup>0.73</sup>)

Within a class of solid feed, the digestibility plays an important role in determining voluntary intake of young ruminants. There is a close linear relationship between herbage consumption of



grazing calves and the herbage digestibility in the range 68 to 82 % (Hodgson, 1968) (Figure 1.3). Work in Ireland showed that the feed intake of weaned calves decreased when the quality of the grass declined (Gleeson, 1971). Others' work supported this relationship and further suggested that the other sward characteristics, like herbage mass, green:dead ratio of the herbage and the sward structure also had significant effects on herbage intake (see following section).

This relationship is similar to that in adult ruminants except for the possibly greater sensitivity of young ruminants to changes in digestibility. This may be due to the effect of the behavioural factors upon solid food intake in young ruminants (Hodgson, 1971c).

Because of the selective grazing, herbage allowance has marked influence on herbage intake. But when the herbage allowance is generous, the digestibility exerts the dominant influence on herbage intake of calves (Hodgson et al., 1977).

#### (5) The processing of the solid feed and its physical form

The processing here generally refers to the grinding and pelleting of solid feed, especially roughage.

The phenomenon that grinding and/or pelleting solid feed, especially roughage, increase voluntary solid feed intake has been observed by many workers. Milling of dried grass increased both solid feed intake of calves and their growth rate (Misson, 1963, Lonsdale and Tayler, 1969). Grinding and then pelleting the dried grass increased DM intake of calves up to 32-50% (Hodgson, 1971a, 1973).

The increase may be attributed to the following effects:

1. the finer particle of the coarse feed after grinding and pelleting increases the passage rate of digesta. It is generally agreed that small particle size is associated with faster passage rate of digesta. A negative correlation has been found between intake and modulus of fineness of the dried grass (Wilkins et al, 1972, Milne and Campling, 1972). Ruminating time is negatively correlated with feed particle size.

2. the change of bulk density of the solid feed. The collapse

of the cell wall structure alters volume of the feed (Church and Pond, 1982). The bigger bulk density, especially when the feed is pelleted, makes the ingestion easier. Measured by eating rate (g DM/min), calves took much less time to eat similar amount of pellets compared with dried grass before grinding and pelleting (0.06 - 0.07 v 0.24g DM/min) (Hodgson, 1971a).

#### (6) The DM content of the feed

The low dry matter content due to rain or other reason appears to depress herbage intake. Arnold (cited from Labastida, 1979) showed that dry matter content below 10% depressed voluntary intake in sheep. A positive correlation between dry-matter content and herbage intake has been observed when fresh cut herbage was fed to cattle under indoor feeding conditions (Halley and Dongall, 1962). Sheep ate significantly more wilted Tama ryegrass (dry matter content 20.2% ) than fresh immature Tama ryegrass (containing 12.5% DM) (Wilson, 1978). But the effect of water content was not important when more mature Tama ryegrass was fed, probably because then the digestibility tended to be the first limiting factor. This effect is possibly due to the smaller intake amount per mouthful when the feed is wet. Therefore, calves intake is more likely to be influenced but no data are available in this field.

#### 1.2.2.3 The Genotype of the Animal

The effect of genotype on feed consumption may be separated into three possible mechanisms.

1. general size difference, birth weight, mature weight etc. between species, breeds or genotypes within breeds,
2. effect of the difference in production potential,
3. other differences, such as thickness of skin causing the different requirement in cold environment.

The size difference may result in difference in total intake, but such differences often disappear or become smaller if body weight or metabolic body weight is considered. Work in NZ with high breeding

index (HBI) and low breeding index (LBI) cows showed that there was no difference in herbage intake between high breeding index (HBI) and low breeding index (LBI) Friesian cows but there was a trend that HBI cows tended to eat more, based on metabolic weight, especially at high herbage allowances (Davey et al., 1983). With HBI & LBI non-lactating Jersey cattle, Bryant(1983) obtained similar result but he found HBI Jerseys tended to eat more at low herbage allowances than LBI Jersey cows.

Mather (1959) and Freeman (1975) reviewed the literature on the genetic differences in food intake control of ruminants. They found that part of the variation in intake and the capacity to consume feed had a genetic basis. They concluded that the repeatability of consumption variation was large enough for cows to be effectively selected for the purpose of improving intake rate.

#### 1.2.2.4 The Environmental Effect

For grazing calves, they are subject to the influence of more environmental factors. So their energy requirement and consequently herbage intake are likely to be dependent upon the change of environment, mainly climate. Those calves reared under indoor condition have more constant condition in terms of temperature and wind velocity.

Calves and lambs grazing pasture ate more solid feed than indoor calves and lambs fed fresh cut grass (Chambers, 1961, Penning & Gibb, 1979). The increased activity of grazing calves requires more energy for maintenance than indoor feeding calves.

Generally speaking, temperature has a negative influence on voluntary intake.

Another important environmental factor influencing voluntary intake is rainfall. Its effect on intake may be comparable with the low dry matter content of the herbage or may merely increase the soil contamination of pastures and hence depresses the intake.

### 1.3 THE DIGESTION OF MAIN NUTRIENTS

Calf digestion can be separated into two types: pre-ruminant digestion and ruminant digestion. But it is notable that for a variable period of time before weaning both types of digestion co-exist and the interaction between them is quite possible and may be important in the development of calf digestion.

Calves digest the nutrients from colostrum milk and other milk substitutes at birth in a way similar to monogastric animals. As they grow and after solid feed is ingested, the rumen microflora are gradually established, so does the rumen function. The importance of rumen fermentation in calf nutrition at this period depends primarily upon the amount of solid feed ingested.

#### 1.3.1 The Digestion of Milk or Other Liquid Feeds

Milk or other liquid feeds can be digested much more efficiently than solid feed by young calves. The digestibility of milk and good liquid feed can be as high as 95 % while the highest value of digestibility of dry matter that can be achieved in the ruminant calves is about 82 % (Blaxter, 1962). The enzymes secreted from the calf itself carry out the process of milk digestion in the abomasum and small intestine.

##### 1.3.1.1 The Enzyme Activity in Salivary Juice

The development of the salivary gland is gradual (see section 1.2.1.3). A variable amount of salivary juice is secreted in the course of feed ingestion depending upon the feed offered and the age of the calf and possibly the balance of water and electrolytes.

It has been found that there is at least one kind of lipase, called pregastric esterase (PGE) in saliva (Roy, 1980). Recent work (Joyce, 1982) demonstrated that it is a single enzyme with a molecular weight value of 52,000.

Hydrolysis of lipid in the mouth is insignificant because of the short time during which feed stays there. It mainly occurs in the

abomasum (Roy, 1980) because of (1) the suitable pH environment there and (2) the prolonged period during which the feed is in the abomasum. PGE functions most efficiently at pH 4.5 - 6.0 (Grosskopf, 1965). It may be detected in the small intestine (Otterby et al, 1964b) but its activity was minimal (Gooden, 1973) apparently due to the high pH value in the small intestine.

PGE acts preferentially on the butyrate groups (c4:0) in butterfat triglycerides, which account for about 33 % of the milk triglycerides (wt:wt) (Grosskopf, 1965, Ramasey, 1962, Otterby et al, 1964a). It was relatively more active in hydrolysing butterfat and lowest for refined lard and tallow (87 v 14%) (Siewart and Otterby, 1971).

PGE activity declines as the calf grows but there is no general agreement on when its activity declines (Grosskopf, 1965, Young et al., 1960).

#### 1.3.1.2 The Digestion in the Abomasum

The abomasum is the main site where milk digestion, especially protein and fat digestion starts.

##### (1) Pregastric Esterase (PGE) Activity and Fat Digestion

As discussed above, the hydrolysis of fat by PGE occurs in the abomasum. This process continues until the pH value of the abomasum is decreased to the extent that the PGE activity is completely destroyed (pH<2.0 - 2.5). So, its activity is present in the abomasum for a few hours after a feed. Mylrea (1966) showed that the pH value of the abomasum was in the range of 4.5-6.2 during 30 min to 3 - 5 hours after a feeding.

PGE appears to be particularly important for the first week of life since the pancreatic lipase activity is low by then (Huber, 1969). At an older age, it may still digest large amounts of lipid. Nearly 70% of the long chain fatty acids in milk or 37.5 % in fatty whey could be digested and absorbed without pancreatic lipase but this was lower than in a normal case (milk long chain fatty acids 96.5% and

82.7% for fatty whey) (Gooden and Lascelles, 1973). On the other hand, pancreatic lipase is also active enough to digest lipid in older calves. There was no difference in fat digestibility between milk fed orally and by rumen infusion (Russell et al, 1980).

## (2) Protein Digestion

Clotting of the milk protein-casein, is essential for normal digestion of protein in calves. The formation of clots in the abomasum of the calves is quick and complete for normal whole milk. It is the function of rennin (Berridge, 1945). In normal healthy young calves fed fresh whole milk, clotting of casein occurs within 3 - 4 min of a meal being ingested (Mortenson et al., 1935) while the whey protein begins to be released into the duodenum within 5 min after feeding (Radostits and Bell, 1970). The clotted casein is degraded as a result of the action of rennin and/or pepsin with the presence of gastric acid (HCl).

However, clotting does not occur with plant protein and does not occur properly with milk processed at excessive temperature. This may be associated with their ability to stimulate the secretion of gastric acid and enzymes. It is observed that the secretion of gastric acid and enzymes were depressed when over-heated milk protein was fed (Williams et al., 1976, Garnot et al, 1977). This may reduce the proteolysis in the abomasum (Leibholz, 1975). Consequently, more indigested protein escaped into the duodenum (Tagari and Roy, 1969, Johnson & Leibholz, 1976).

The amount of acid secreted into the abomasum increases with age (Porter, 1969). So the pH value of it generally decreases as the calves grow (Kesley et al., 1951).

Pasteurized milk, "severely heated" skim milk powder, and most non-milk protein that are included in milk replacer or high fat content milk replacer (>200g fat/kg DM), reduce the secretion of HCl (Ternouth et al, 1974, 1975). The secretion of rennin seems also to be reduced by "severely" preheated skim milk powder, fish protein or soya bean flower (Williams et al., 1976) or whey protein (Garnot et al., 1977).

### (3) Carbohydrate (CHO) Digestion

The main CHO in milk or milk substitutes is lactose. There is no evidence to show that CHO undergoes any digestion in the abomasum of young calves since salivary amylase and other CHO digesting enzymes are either absent or are present in insignificant amounts in young ruminants (Otterby & Linn, 1981).

#### 1.3.1.3 The Digestion in Small Intestine

The digestion in small intestine is mainly carried out by the pancreatic enzymes and enzymes from the small intestine. The proteolytic enzymes from the abomasum are not active because of the high pH value in small intestine.

Generally speaking, after the digestion in the small intestine, most of the nutrients are in an absorbable form - amino acids, monosaccharides and fatty acids etc..

The activity of most enzymes increases progressively after birth but adult ruminants are lacking in lactase (Roy, 1980). Therefore, digestibility of most nutrients increases with age except for lactose.

### (1) Carbohydrate (CHO) Digestion

It appears that calves at an early age can only digest lactose and lack the enzymes for digesting starch. Lactose is digested in the small intestine by  $\beta$ -Galactosidase, i.e. lactase, which is secreted by the small intestine. The calves can absorb some monosaccharides including galactose and glucose but they can not absorb fructose. Morrill et al. (1970) concluded that preruminant calves under 100 days of age made insignificant use of starch. The poor utilization of starch by young calves is shown clearly by either the reduced growth rate after replacing lactose by starch (Huber et al., 1968) or the reduced blood sugar level after such feeding.

The ingestion of starch may even influence the digestion of other nutrients. Significant decreases in dry matter, CHO and protein

digestibilities were noted as the dietary starch increased (Ralston, 1972), but the reason for this is not quite clear. It was suggested that the disappearance of a small proportion of starch in the alimentary tract of preruminant calves seemed to be due to the microbial fermentation in the caecum and colon (Norris, cited from Ralston, 1972). Also, the sucrose disappearance in young calves may be associated with the activity of microorganisms in the lower tract because sucrase is virtually absent in young calves (Otterby & Linn, 1981) and it is poorly digested (Okamoto et al., 1959). If this is so, then the normal digestion of other nutrients may be interfered by the microflora in the small intestine which rely on these CHO materials. The activity of enzymes may be manipulated by the gradual change of feed that is offered. Maltase and isomaltase activity increases as the calves grow. But it may be promoted by the intake of starch (Shaw et al., cited from Ralston, 1972). On other hand, lactase activity decreases with age (Dollar & Porter, 1959). It may last longer if milk is continuously offered (Huber et al., 1967, Roy et al., 1973).

## (2) Fat Digestion

Pancreatic lipase is of major importance in the hydrolysis of triglycerides containing long chain fatty acids. Its action seems to be enhanced by the pre-action of salivary lipase (PGE) (Edwards-Webb & Thomason, 1977). But as the calves grow, the activity of it increases. The pre-effect of PGE is no longer important. Russell et al. (1980) showed that there was no difference in digestibility between milk fat normally ingested and rumen infused.

The activity of pancreatic lipase is greatest for butterfat (Adams et al., 1959) though all commercial vegetable oils used in milk substitutes can be hydrolysed by it with release of saturated and unsaturated fatty acids (Roy, 1980).

## (3) Digestion of Protein

Pancreatic juice contains protease, chymotrypsin, trypsin etc.



Some evidence showed that the protease activity of pancreatic tissue increased during the first few days of life (Huber, 1969). Furthermore, for the production of the total proteolytic enzymes, their activity per unit body weight increases with age until at least 180 days old.

The increased activity of pancreatic proteolytic enzymes and the increased flow rate of pancreatic juice possibly account for the increased digestibility of many non-milk proteins as calves grow. Feeding high level of soy protein results in a reduced rate of pancreatic secretion and low proteolytic activity but this may be partly due to the anti-trypsin inhibitor in this protein. Some evidence suggested that soybean meal caused morphological changes in the small intestine walls. Similarly, the inclusion of a "severly" pre-heated skim milk powder causes a reduction in pancreatic enzyme activity. Differences in proteolytic enzyme activity between animals may also exist. Friesian calves have a higher digestibility of protein than other breeds at the same age (Roy, 1980).

#### 1.3.1.4 Immunoglobulin (Ig)

Ig is an important component of colostrum which has a vital function in calf health in early age. Its content in colostrum is as high as 38.5 to 47.6 % of the total dry matter. The most important function of it is its immune effect for new born calves.

In order to keep the immune function of Ig, it must be absorbed intact. This may be achieved by the low proteolysis in the abomasum in new born calves probably due to the low HCl secretion and so nearly neutral environment of the abomasum.

The absorption of Ig by new born calves is a complicated process. It is taken up by the epithelial cells of the small intestine by the process of pinocytosis (engulfing of fluid globules by pseudopodia) and passed into the lymph spaces and then into the blood circulation by way of the thoracic lymph duct (Combine et al., 1951a, b).

The ability to absorb Ig appears to be limited by some known and unknown factors. It was found that the proportion of Ig<sub>m</sub> absorbed was negatively related to the amount ingested (Stott and Menefee, 1978).

Because of the rapid decline of Ig absorbing ability after birth, it is generally suggested that colostrum should be fed as early as possible within first 24 hours. The absorption of Ig is limited to the first 24 to 36 hours of life (James et al., 1976).

### 1.3.2 The Digestion of Solid Feed

It is well known that in the digestion of solid feed, the rumen plays an important role. As discussed above, the rumen develops as the calves grow, especially after solid feed is ingested, so does the rumen function. Calves can digest solid feed as early as 2 weeks of age. Calves of 3 weeks of age can digest grass as efficiently as the adult ruminant and that this efficiency is achieved within 2 days of the grass being fed (Preston et al., 1957). Calves weaned at 3, 5, 7 weeks of age fed a grain based starter mixture had a similar DOM in the first week after weaning (77.1, 78.7 and 78.3% respectively). It was still similar at 7, 13 and 19 weeks of age. A similar result was also obtained by other people (McArthur, 1957, Penning and Gibb, 1979) with calves and lambs in early age. But it is still not clear whether age or body weight has any influence on digestibility. Jeffery (1976) using sheep observed a significant correlation between DDM and LW, for every Kg LW increase, digestibility increased 0.34%. Minson & Ratcliff's experiment (1982) showed that LW had significant effect on low quality roughage digestibility (DDM<50%). Digestibility of herbage DM by calves of 5-15 weeks of age has been reported as approximately 75% (Preston et al., 1957). But the digestibility of low quality feeds, such as hay or high roughage content diets was lower than that in adult ruminants (Flatt et al., 1959 cited from Roy, 1980). This is in accordance with the fact that the rumen protozoa population and cellulose digesting ability develop later than other type of microorganisms (Singh et al., 1983).

#### 1.3.2.1 Rumen Fermentation

The rumen fermentation is carried out by the rumen microflora. It is generally agreed that in the normal farm situation the

establishment of microflora is not a limiting factor for solid feed digestion.

The amount of VFAs, end products of fermentation, increased with the age of the calves although no differences in their concentration in the rumen have been observed between calves of 8 and 14 weeks of age. This could be due to either the increased rumen volume at the same period (see section 1.1) or the developed ability of the rumen wall to absorb VFAs. A marked increase of VFAs concentration was observed (Table 1.4). The feed used in their experiment was concentrates which are fermented very quickly. With lambs from 15 to 40 weeks of age, no changes attributable to age or body size were observed with the production rate of volatile fatty acids in the rumen per unit feed intake and the rate of absorption of VFAs from the rumen (Weston & Margan, 1979).

Though the digestion of solid feed in calves is largely similar to that in adult ruminants, in terms of microbial function, there are likely to be some differences in detail. Young calves produced higher levels of lactic acid, the highest occurred at about 1 month of age (Lengemann and Allen, 1955). A slightly higher proportion was found in calves given all concentrate diets compared with those given an all-hay diet at 16 weeks of age (Stobo et al., 1966a,b). The ratio of three main fermentation products, acetic, butyric and propionic acids and the total amount of them change markedly at an early age (Table 1.4).

Table 1.4 VFA Concentrations in the Rumen Liquor, (Molar)

DIETS*															
AGE		MILK				+	GRAIN				+	GRAIN + HAY			
(wks)	T	A%	B%	P%	+	T	A%	B%	P%	+	T	A%	B%	P%	
3	59	55	17	28		97	60	10	30		226	53	15	32	
5	205	46	29	25		425	49	27	24		242	58	22	20	
7	284	48	28	24		374	49	30	21		346	51	25	24	
11	318	47	25	27		694	49	30	21		584	55	22	23	
15	210	44	26	30		536	50	19	31		854	50	28	22	

From: Flatt et al. (cited from Roy, 1980)

\*T=Total volatile fatty acids (molar);

A=Acetic; B=Butyric; P=Propionic

It showed that calves eating roughage can reach higher fatty acid concentration and its rumen butyric acid proportion is higher than calves offered concentrates. In all calves, the butyric acid proportion in the total VFAs concentration increase as the calves grow while the proportion of the acetic and propionic acid decreases. The fact that milk fed calves also had a gradual increase of VFA concentration with age suggests that 1) milk fed calves also have rumen fermentation most probably due to the milk escaping into the rumen and 2) more milk escape into the rumen in older calves since the total VFAs concentration increases with age.

The young calf's ability to digest different nutrients varies considerably. Starch digestion is essentially complete (98-99%) (Huber, 1969). But the digestion of cellulose is very poor. As for protein, part of the herbage protein is in association with cell wall and the digestibility of this proportion of protein is likely to be positively correlated with the cell wall organic matter digestibility. So it may not be well digested by young calves.

### 1.3.2.2 Some Characteristics of the Rumen Fermentation

The rumen of young calves is still in the developing stage even if they can digest high quality solid feed satisfactorily. Furthermore, before weaning, they ingest both liquid and solid feed. The liquid feed ingested may have an effect on the rumen fermentation as discussed below.

#### (1) The possible interaction of milk and solid feed digestion

Such an interaction can be either due the effect of milk on fermentation (if it appears in the rumen) or its effect on digesta passage rate from the rumen or the effect of solid feed on milk ingestion and digestion. At present, the effect of milk on solid feed digestion seems to be supported by some evidence. For example, the establishment of adult type organisms and cellulose digestion were hindered by liberal milk feeding (Lengemann & Allen, 1959).

There are two possible ways for milk getting into the rumen:

1. The backflow of milk from the abomasum. This may be caused by overfeeding of liquid feed to the calves and other factors.
2. The incomplete closure of oesophageal groove. This could result from either genetic or management factors, like feeding method, milk temperature etc..

The backflow of milk from the abomasum may help to inoculate the rumen because the abomasum of young calves has a large and diverse population of lactobacilli (Mann & Oxford, 1955). The ingested milk may also bring some bacteria into it. But the accumulation of milk in the rumen and the fermentation of the milk are generally considered to be detrimental to the calves (Radostits and Bell, 1970, Roy, 1980) but little evidence on how it influences the calf performance is available at present. With artificially fed lambs, a so-called "maladjustment syndrome" was first observed by Lawlor & Kealy in 1971. The lambs drank less milk and had a similar low pH value in the rumen as in the abomasum presumably due to the backflow of abomasal content or escape of milk into the rumen in the meal. Arsenault et al. (1980) found that the lambs with "maladjustment syndrome" had shown high gas

production level and low pH in rumen. Using calves of 14 - 15 weeks old, Keane and Harte (1982) showed that there was no difference between the responses to milk feeding in liquid form and solid form. They suggested that the tiny particles of milk powder, in fact, were passed down to the abomasum very quickly instead of undergoing fermentation in the rumen so they suffered little loss. Of course the possible disturbance it may cause on digestion is also likely to be minor. But for young ruminant, this conclusion may not apply.

Farming experience and some experimental results indicate that suckled calves grow faster and have a lower incidence of diarrhoea than calves fed milk from pails (Chambers and Alder, 1960, Kuzmin and Bagrii, 1965, Moss, 1977). But some comparisons of artificial teat and pail feeding of milk also result in insignificant difference in calf performance (Kuzmin & Bagrii, 1965, Kesler et al, 1956, Fallon & Harte, 1980). The complete closure of the oesophageal groove, shown by some workers (Lawlor et al., 1971) in both calves and lambs, is essentially dependent upon the feeding procedures. Sucking from a teat is a necessary stimulus to the complete closure of the oesophageal groove. On the other hand, Abe et al. (1979) showed with both lambs and calves that the complete closure of the oesophageal groove in early age is independent of the feeding procedures and the type of liquid feed fed provided a training to drink from buckets or pails was given. It appears that after training young ruminants may set up the conditional reflex closure of the oesophageal groove though there will always be some individuals which have malfunctions of the oesophageal groove.

#### 1.4 ENERGY AND PROTEIN REQUIREMENTS OF YOUNG CALVES

The requirements of calves for energy and protein are closely associated with their body weight and expected growth rate. Other nutrients are also quite necessary for normal growth of the calves though they are not likely to be deficient in normal situations.

#### 1.4.1 Energy Requirements

In estimating energy requirements of an animal, the factorial method is commonly used (ARC, 1980), i.e. the energy requirement is arbitrarily separated into maintenance requirement, growth requirement and lactation requirement etc.. These requirements are estimated separately and the summation of them is considered to be the total requirement. The energy requirement of an animal can be estimated by the following methods:

1. Calorimetric balance methods - direct and indirect;
2. Slaughter method;
3. Inferences from measurement of liveweight gain.

##### 1.4.1.1 Maintenance Requirements

Maintenance energy requirement is the energy used by animals in the following three ways:

1. the basal metabolism, which is the heat produced as a result of oxidation of body tissue to provide energy for respiration, circulation, muscle activity and other vital process, together with a small loss of energy in the urine;

2. the heat produced as a result of normal voluntary activity such as drinking, walking, playing, standing up and lying down;

3. the heat produced in the metabolic processes that occur within the tissues as a result of feeding sufficient energy in the diet to satisfy both the basal metabolism and the energy required for voluntary activity (the heat increment of feeding).

Fasting metabolism can be used as a base to estimate the maintenance requirement of animal. It can be obtained with the animal in a calorimeter, directly measuring heat production and urine energy under the following conditions:

- a. the animal is in the post-absorption stage;
- b. environmental temperature is within thermoneutral range.

Table 1.5 Some Estimates of MEm of Calves

SOURCES	MJ ME/Kg <sup>0.75</sup>
Blaxter & Wood (1952)	0.455
Gonzalez-Jimenez & Blaxter (1962)	0.469
Van Es <u>et al.</u> (1969)	0.436
Holmes <u>et al.</u> (1975)	0.409
Holmes & Davey (1976)	0.393
Kirchgesser <u>et al.</u> (1976)	0.431
Brookes & Davey (1977)	0.394
Johnson & Elliott (1972)	0.423

Fasting heat production is not a constant value but varies with the level of feeding (Marston, 1948) and growth rate of the animal immediately prior to starvation (Graham et al., 1974). Fasting metabolism is not directly related to body weight but with the metabolic weight.

The estimate of maintenance requirement of metabolic energy from many workers in different countries at different time are generally in satisfactory agreement except for a few (Table 1.5). Generally speaking, the more recent estimates are somewhat lower than the early ones. This is also acknowledged by Roy (1984) in a recent review. It seems that the estimates from New Zealand are bit lower than those from other countries. But the reason for this is by no means clearly understood.

Factors affecting maintenance requirement include age, level of activity, physiological stage, sex, variation between breeds and individuals and the properties of the diet.

#### 1. Age:

Fasting metabolism per unit metabolic weight is higher in young growing animals than in mature animals (Blaxter et al., 1966, Graham



and Searle, 1972a, Kay, 1976, Orskov et al, 1976). The basal metabolism increases during the first 2 to 3 days of life probably as a result of the calf's effort to adapt itself to its new environment.

## 2. Sex:

Sex effect on the fasting metabolism appears to be significant only in mature animals, male is usually higher than female.

## 3. Variation with Breeds and Individuals:

The effect of breed has been shown by some workers in some breeds (Blaxter & Wainman, 1964, Vercoe & Frisch, 1974, Webster et al., 1976). But in other experiments, such effect was shown to be small if any (Vercoe, 1970, Patle and Mudgal, 1975, Holmes et al., 1978). The variation between individuals is about as much as 8 - 10% (NRC, 1978). Friesian calves are less affected by cold temperature than Jersey calves (Holmes & McClean, 1974).

## 4. Level of Activity:

Active animals have a higher maintenance requirement (Osuji, 1974). Under low temperature, the animals appear to increase muscle activity in order to maintain body temperature, so the maintenance requirement increases (Holmes & Mclean, 1975). For the calves on pasture, they spend longer time and more energy walking around to graze herbage.

## 5. Composition of the Ration and Km Value:

Km is the efficiency of ME used for maintenance. It is strongly influenced by the composition of the ration. The inefficient use of ME is shown by the heat increment of feeding, which is caused by the following processes:

(1) The process of digestion of feed in the alimentary tract requires energy (Blaxter, 1962, Baldwin, 1968, Osuji, 1974). Logically, the nature of the diet influences this part of energy loss (Graham et al., 1974).

(2) Heat arising from the fermentation of solid feed in the rumen, usually about 5 - 10 % of gross energy of the solid feed

(McDonald et al., 1973). Fermentation losses are minimal in the calf before the rumen becomes functional.

(3) The energetic inefficiency by which absorbed nutrients are metabolized to provide ATP for maintenance (Blaxter, 1962, Armstrong & Blaxter, 1957).

Most of the estimates on calf maintenance requirements per unit metabolic weight or per unit LW were from calves fed milk or milk substitutes (Table 1.5). Some experiments showed that there was no difference between these and those obtained from calves fed hay or pelleted feed (Holmes et al., 1978).

#### 1.4.1.2 The Growth Requirements

The growth of animals, in fact, is the deposition of protein and fat plus water in the live weight gain. The energy content of protein is lower than that of fat. 100g protein contains about 2,437 KJ NE while fat contains about 3,933 KJ net energy per 100 gram (McDonald et al., 1980). On the other hand, the energetic efficiency of fat synthesis is higher than that of protein. So, the growth requirement is not necessarily linearly related to the live weight gain.

In order to estimate the growth requirement, the following parameters must be obtained first:

- 1) The expected growth rate;
- 2) The energy content of the live weight gain;
- 3) The Kg or Kf value.

- 1) The growth rate of calves

Calves can grow as fast as 1 to 1.5 kg/d provided whole milk or high quality milk substitutes are offered ad libitum. But for dairy herd replacements rearing, such high growth rate is not necessary and is uneconomic. It may also be harmful to later milk production. Many experiments have clearly shown that high growth rates (>0.7 kg/d) before mating have detrimental effect upon milk yield in first lactation and even the first few lactations (Swanson & Spain, 1954, Garstand & Mudd, 1972, Gardner et al., 1977, Little and Kay, 1979).

This may be due to the calving problem (Little and Kay, 1979) and/or the abnormal development of mammary gland (Sejrsen et al., 1982, 1983). The mammary secretory tissue development was retarded by a high level of feeding.

There is no general agreement on whether the low growth rate at an early age, especially in the first few weeks has a permanent effect on the later growth and reproductive performance. Work at Massey University showed that the difference in liveweight due to the different feeding level in the fourth to ninth week of age disappeared by 18 weeks of age, but it remained if the difference resulted from different feeding levels in the first 4 weeks of life (Davey, 1962). A conclusion, therefore, was drawn that the growth rate in the first few weeks of life is critically important to the future growth and low liveweight gain over this period could have a permanent effect on growth (Davey, 1974). This is confirmed by others' work (Everitt, 1972, Reardon, & Everitt, 1972, Brookes & Davey, 1977). In contrast, Jenny & O'Dell (1981) showed in his work that the calves could be maintained near birth weight for up to 3 weeks without detrimental effect on performance at 12 weeks of age. Experiments with Merino sheep (Allden, 1979) showed that nutritional deprivation in early life did not affect the reproductive performance of the ewes or the birth weights and weaning weights of their progeny. Caution must be paid in the explanation of this result since the milk yield of ewes is generally much lower than dairy cows even based on the yield per unit liveweight. Consideration is usually given to the following few aspects in determining the calf growth rate: 1) low calf mortality, 2) to achieve the target weight at various growth stage. It is generally recommended that 0.5 to 0.6 kg/d is the optimum growth rate for heifer rearing (Davey, 1974, Scott & Smeaton, 1980).

## 2) The energy content of liveweight gain

The energy content of liveweight gain is another important factor determining the energy requirement for growth. As discussed above, the empty body weight gain includes protein, fat and water components. The ratio of them determines the energy content in per unit weight

gain and it varies primarily with the following few factors:

- 1) Growth rate;
- 2) Sex;
- 3) Breed size;
- 4) Age;
- 5) Quantity and quality of feeds.

Furthermore, for liveweight gain, a variable part of it is the increase of gut fill which contains undigested feed and undigestable feed residue. The percentage of it in liveweight gain varies with the feed properties and calf age. The ruminant calf has high gut fill whereas calves eat high quality feed have less gut fill.

#### 1) Growth rate:

The faster the animal grows, the higher the fat content in the gain, so the energy content is also higher (Lofgreen & Carrett, 1968, Searle, 1970, Graham & Searle, 1972b). One equation for estimating the energy content of empty body weight gain is as follows (ARC, 1980):

$$E = (4.1 + 0.0332W - 0.0000009W^2) / (1 - 0.1475 \text{ nWG})$$

where E is the heat of combustion of a gain in liveweight (MJ/Kg),  
W is liveweight and nWG is liveweight gains per day.

#### 2) Sex:

Male animals have higher protein and lower fat content in the weight gain, therefore, the energy content per unit weight gain is lower (Garrett, 1970).

#### 3) Breed:

Large sized breeds have a higher energy content per unit weight gain (ARC, 1980).

#### 4) Age:

As the calves grow, the fat content in live weight gain also increases. Therefore, the energy content of older calves is higher

than younger calves. Gut fill increases with an increase in retention time of digesta in the alimentary tract so factors such as the digestibility of the feed and the particle size of it have great influence.

#### 5) Type of Diet:

The protein content of the diet and protein:energy ratio have an effect on the composition of body weight gain (Andrews & Orskov, 1970a,b, Orskov et al, 1971, Donnelly & Hutton, 1976a,b, Orskov et al., 1976). Low protein diet results in high fat content.

Besides, compensatory growth after a change of diet from low protein content to high protein cause an increase in fat content and decrease of water content (Orskov et al., 1976). It may also have an influence on energy content of the liveweight gain (Graham & Searle, 1975).

#### 3) The efficiency of ME used for growth (Kg)

The ME ingested above maintenance level is used for growth in young growing calves. The efficiency of ME used for growth, Kg, is probably lower than Km though some people suggested that they are similar, namely 77 to 85%. Recent work gave the Kg value 0.687 or 0.63 (Roy, 1984). Table 1.6 lists some estimates of Kg value.

The efficiency of use ME for gain(Kg) is determined essentially by the ratio of protein and fat in per unit weight of gain provided other nutrients are not deficient. It is known that it is much more efficient to convert feed ME to body fat energy than to protein energy. Some studies showed that the efficiency with which simple stomach species or infant ruminants deposit fat is about 0.70 but that of the protein deposition is much lower, about 0.45 (see ARC, 1980). The efficiency of fat deposition is in accordance with biochemical calculation (Armstrong, 1969). A big difference between adults and young calves is the fat percentage in liveweight gain. In adult animals, the energy retained as fat varies from 85 to 95 % of total energy retained while in some young animals, fat retention may account for as little as 50 %. Therefore, as the animals grow, the efficiency

of utilization of surplus ME for growth increases. But some results showed that there was no significant increase in Kg as the animals grew (Blaxter et al., 1966, Van Es et al., 1969).

Table 1.6 Some Estimates of Kg in Pre-ruminants

SOURCE	SPECIES	EFFICIENCY
Gonzalez-Jimenez & Blaxter (1962)	Calf	0.77 - 0.81
Van Es <u>et al.</u> (1969)	Calf	0.69
Vermorel <u>et al.</u> (1974)	Calf	0.69
Webster <u>et al.</u> (1976)	Calf	0.72
Holmes <u>et al.</u> (1975)	Calf	0.67
Walker & Jagusch (1969)	Lamb	0.71
Walker & Norton (1971)	Lamb	0.69

The quality of the feed also has a large influence on Kg value. For calves and lambs receiving milk or milk substitutes, the efficiency (Kg) is higher than that of ruminanting calves.

The Kg value from ruminant calves may be quite similar to those given above. Holmes et al. (1978) reported 0.51 to 0.57.

#### 1.4.2 The Protein Requirements

Similar to energy requirement, the protein requirement of the animal (expressed as total tissue nitrogen requirement, T.N.) includes two parts, one for maintenance, another one for production purposes. The protein requirement for maintenance is assumed to be equal to the endogenous urinary nitrogen excretion (UN(E), g/d) and faecal endogenous nitrogen losses plus losses of nitrogen in hair and scurf. The protein requirement for production purposes is that part which is expected to be retained in the tissues in growing animals or excreted in milk for lactating cows (RN or LN, g/d). The maximum

requirement of an animal for protein can be estimated by the following way. Increasing the protein level of diet gradually until no further increase in some measured criterion such as liveweight gain is no longer increasing or nitrogen retention ceases (Donnelly & Hutton, 1976a, b, Stobo & Roy, 1973, Black et al., 1973, Black, 1971, Black & Griffiths, 1975) then the highest protein intake is the maximum protein requirement for the animal in question. But the protein level that can support maximum growth rate varies with its quality, namely its amino acid composition.

#### 1.4.2.1 Some Components of the Total Protein Requirements

##### 1. Endogenous urinary N

This is the loss of nitrogen as a result of metabolic processes in the tissues and is assumed to be equal to the amount of nitrogen in the urine if a calf is given a nitrogen-free diet. Therefore, it is more closely related to the metabolic weight of the body. For pre-ruminant calves, the value is between 63 and 82 mg N/kg body weight (Blaxter & Wood, 1951, Shillam & Roy, 1963) or 184 - 193 mg N/Kg<sup>0.75</sup> (Roy et al., 1970). It declines as the calf grows.

##### 2. Metabolic faecal N

The loss of digestive juices, bacterial residue and epithelial cells is the cause of this part of N losses. In general, it is related to both the amount of feed ingested and the quality of the feed. In calves offered whole milk or a good quality milk substitute diet, the value is about 1.9 g N/Kg dry matter intake (Roy et al., 1970). It is small and constant, so, it may be omitted if the apparent digestibility is used (ARC, 1980). But in ruminant calves this value may be much bigger.

##### 3. N content of weight gain

Roy (1980) reviewed some experimental results and proposed that

the amount of nitrogen deposited per Kg weight gain was approximately 26 to 34 g N, i.e. about 162.5 to 212.5 g protein. But because of the variation in body composition, the value is quite variable and higher in slow-growing calves and young calves and calves offered high protein content diet.

#### 1.4.2.2 The Efficiency of Absorbed N in Meeting N Requirements and Biological Value (BV)

They are two related concepts. BV of a protein is defined as the proportion of truly digested N that is retained in the tissues and is used to meet the obligatory loss in faeces and urine, i.e.

$$B.V = \frac{RN + FN(M) + UN(E)}{DN + FN(M)}$$

where RN = N retention

FN(M) = metabolic faecal N

UN(E) = endogenous urinary N

DN = apparently digested N

The BV of milk protein is 80 % or even as high as 90 % (Brisson *et al.*, 1957, Blaxter & Wood, 1952) provided there is an excess of energy and all other nutrients except protein. For pre-ruminant calves, BV is a quite valid measurement of protein utilization in the body. But for ruminants biological value has grave shortcomings as a measure of efficiency of utilization of absorbed amino acid N.

1) dietary N is intensively converted into microbial protein in ruminant calves.

2) it is difficult to accurately measure the metabolic faecal N part of which is of microbial origin.

Therefore a new concept, the efficiency of absorbed nitrogen in meeting nitrogen requirement of the ruminants ( $Kn(v)$ ), is proposed. According to Roy *et al.*'s work (1970) in calves and Black *et al.*'s work (1973) in lambs,  $Kn(v)$  of milk protein is about 0.80 when protein intake is limited. But protein of non-milk origin have lower values. There is also variation in  $Kn(v)$  values between different solid feeds.

It is known that the efficiency of utilization of absorbed amino



acid N depends on:

- 1) How closely the amount and ratio of absorbed amino acids meet the requirements of the tissues;
- 2) The availability of other feed nutrients in meeting energy requirements of the animal;
- 3) The availability of certain micro-nutrients required either in the formation of peptide bonds or in other reactions involved in amino acid metabolism or ATP production.

Though some workers have tried to improve the efficiency of utilization by, for example, supplementing undegradable protein of high quality, the result in animal performance is not constant (Brookes, 1982).

### 1.5 SOME APPLICATIONS IN CALF REARING SYSTEMS

In practice, depending on the calf rearing purpose, there are a wide variety of calf rearing systems. Calf rearing systems involve (1) the amount of milk used in calf rearing, (2) the milk feeding length (weaning age), and (3) feeding techniques used. For every system, modification can always be made according to the conditions and farmers' preference. For example, considerations are usually given to the following four aspects in choosing a herd replacement heifer calf rearing system:

- 1) The amount of milk or other liquid feed required. Feeding calves solid feed is usually cheaper than using milk or milk substitutes. For economic reasons, calves should be weaned at the youngest age possible provided target weights and low rate of morbidity and mortality are ensured (Roy, 1980). In order to achieve this purpose, low milk or milk substitute intake per day in as short period as possible, which encourages solid feed intake, is necessary.
- 2) The convenience of feeding. Generally speaking, calf rearing always coincides with the busiest time of dairyfarmers within one year. Therefore, the low labour costing systems, the ones that can be adapted to some new feeding techniques, such as once daily feeding, low temperature and automatic feeders (drum feeders) are likely to be preferred.

3) Calf health. The major problems encountered in the first month of life are septicaemia and scours. Proper colostrum feeding in the first 24 hours of life is more important than any other treatment possible.

4) Growth rate. Different growth rates are needed for different calf rearing purposes. For heifer rearing, high growth rate is not so necessary as in beef cattle rearing or veal calf rearing.

Because of the significance of herd replacement calf rearing in NZ, the few calf rearing systems discussed below will be more or less used in herd replacement calf rearing. But other information is also used without hesitation if it is useful.

For herd replacement calves, the aim of early rearing usually is to introduce the calves to solid feed, especially pasture at an early age without much disturbance on calf health and future milk production. The following few systems are currently used in New Zealand for herd replacement rearing.

#### 1.5.1 Ad libitum Feeding of Whole Milk or other Liquid Feeds

This system is characterized by the large amount of milk required and low labour cost especially if some new techniques are used. The milk consumption can be as high as 7 to 9 litres/calf/d so the growth rates are rapid. Friesian calves can reach a weight of 70Kg or so in 5 to 6 weeks. The calves may have access to pasture or other solid feeds but the intake of solid feed is negligible.

Single or double suckling (i.e. one or two calves sucking one cow) if the milk yield of cow is high, automatic feeding machines, large drum (say, 200 litres) with teats are other forms of this system. Feed can be whole milk, reconstituted milk or stored colostrum and preserved milk (acidified milk, pH 5.3 - 5.8) (Dawson *et al.*, 1982, Davey, 1980). Dawson *et al.*'s work in 1980 demonstrated that fermented colostrum is an ideal cold ad libitum feed. However, under practical conditions, supplies of colostrum may not always be adequate. Therefore, preserved milk, reconstituted milk and whole milk are also used.

The main advantage is its easy management and low labour cost and

increased liveweight gains. For instance, if feeding calves with stored colostrum or acidified milk, topping up the drum with colostrum or milk is the main job. Parsons and Stewart (1984) showed that calves fed ad libitum took much less time to feed compared with calves fed even once daily (10 vs. 40 min./head/d).

But the large amount of milk it requires is probably the biggest disadvantage of this system. It results in both high rearing cost and a prolonged weaning check in liveweight. Recent work showed that the low pH may limit the milk intake of the calves (Davey, 1980, Dawson *et al.*, 1982). Some other methods may also be used for this purpose, such as diluting milk with water (Roy, 1980), increasing the calf:teat ratio. However, it was shown that diluting had no effect on calf milk intake unless 50% water was added to the milk (Dawson *et al.*, 1982).

In this system, calves can be weaned early if liveweight standard, for example, 70 Kg LW, is used. Friesians can reach 70 Kg LW in 5 to 6 weeks and be weaned. But they must be weaned late if the weaning check is to be minimized.

#### 1.5.2 Restricted Feeding of Milk or Milk Substitutes with Relatively Early Weaning

This system is characterized by the low level of milk feeding and early consumption of solid feed. Milk or other liquid feeds are offered at a restricted level. On the other hand, concentrates and high quality pasture or hay are available both before and after weaning for calves to compensate the lower intake of energy from milk by eating more solid feed (Khouri *et al.*, 1967, Davey, 1972). Below is a general schedule of this system for Friesian calves:

Feed	Amount	Duration(weeks)
Milk	4 litres/calf/d	5 - 6
Concentrates	To appetite	5 - 6
Concentrates	1 Kg/calf/d	6 - 10

Pasture is available throughout

Depending on the availability of concentrates and pasture quantity and quality, calves can be weaned early (3 - 5 weeks of age) or later (8 - 10 weeks of age).

The success of early weaning is dependent primarily upon the quality of the solid feed offered if a relatively high growth rate is required. Concentrates are better than even high quality pasture for early-weaned calves in this case (Byford, 1974) because it is less limited by intake capacity. A concentrate mixture for calf rearing may consist of the following components (Davey, 1980).

60 - 70% cereal grains  
20 - 30% linseed or meat meal  
10% molasses

The main advantages of this system are:

1. Reduce milk or milk substitute consumption. For early weaned calves, only 84 to 140 litres milk are required.

2. Labour cost is also reduced because less milk is handled. Calves can be fed once daily from one week of age provided they are healthy. It is generally agreed that once daily feeding is likely to have little detrimental effect in an early weaning system when restricted amount of milk is fed (Ackerman *et al.*, 1969, Fieber, 1972, Khouri, 1969, Reddy *et al.*, 1971). Parsons and Stewart (1984) demonstrated that, though compared with *ad libitum* feeding, once daily fed calves grew slower (578 v 481 g/d) in pre-weaning period, however, there were not differences in LW at 6 months of age.

### 1.5.3 Traditional Method

This method of calf rearing restricts milk intake moderately (4.5 - 5 litres/calf/d) and pasture is often available to the calves. Because of the interaction between milk and solid feed intake and the relatively low bulk density of pasture, the capacity of herbage consumption develops slowly. In other words, calves are not likely to be early weaned in this system. Usually they are weaned off milk at about 8 - 10 weeks old. Therefore, the total milk consumption is much higher than the above system (section 5.2) (250 to 350 l milk/calf).

## CHAPTER 2

### MATERIALS AND METHODS

#### 2.1 EXPERIMENT DESIGN AND PROCEDURE

The experiment was of a complete randomized block design. There were four blocks each with four calves. Within each block there were two high breeding index calves (HBI, BI of parents =134) and two low breeding index calves (LBI, BI of parents =103). One calf within each breeding index group was fed high level of milk (HM, 6 l milk/day) and the other was fed low level of milk (LM, 4.5 l milk/day). The four groups were classified as follows:

Group HH -- this group of calves of HBI received HM treatment.  
Group HL -- this group of calves of HBI received LM treatment.  
Group LH -- this group of calves of LBI received HM treatment.  
Group LL -- this group of calves of LBI received LM treatment.

The four groups were used to compare:

1. the responses of calves to different milk feeding levels (HM or LM) in herbage intake, growth performance, digestion and nitrogen balance and
2. the interaction of feeding level and calf genotype (expressed as breeding index).

The experiment included two main periods, I and II. The calves' growth performance was further observed until they reached 21-25 weeks of age (period III) (see Table 2.1).

The experiment lasted from August 30 to November 15 in early spring at Massey University, Manawatu area, New Zealand.

Table 2.1 The Experimental Description

Period	Age(weeks)	Group	Food	Amount
I	3-7.5	HH	Milk	6 litres/calf/d
			Fresh cut herbage	ad libitum
		HL	Milk	4.5 litres/calf/d
			Fresh cut herbage	ad libitum
		LH	Milk	6 litres/calf/d
			Fresh cut herbage	ad libitum
		LL	Milk	4.5 litres/calf/d
			Fresh cut herbage	ad libitum
II	7.5-10.5	HH		
		HL	Fresh cut herbage	ad libitum
			(all calves treated uniformly)	
		LH		
III	10.5-23	LL		
		All Calves Grazing Pature together as One Mob		

### 2.1.1 Period I

Period I, pre-weaning period, was the main experimental period. Calves were offered either a high level or low level of milk. The objective of this period was to compare 1) the responses in herbage intake, the liveweight gain, digestibility and nitrogen retention 2) the interaction between milk feeding level and breeding index in the above mentioned responses in this period.

Therefore, except for milk feeding level, the calves were treated uniformly. In order to encourage the solid feed intake and ensure the maximum intake of herbage for all four groups of calves, fresh cut herbage was offered ad libitum, which means that the herbage offered was at least 20% more than the calves could eat. The calves were weaned in two days at the end of this period, 7-8 weeks of age.

### 2.1.2 Period II

The objective of this 3 week period was to observe the effect of milk feeding level on calf performance and herbage intake shortly after weaning and its interaction with breeding index.

Because what was to be observed was the effect of pre-weaning treatment, all calves in this period were to be treated similarly in order not to bias the comparison. Herbage was still offered ad libitum.

### 2.1.3 Period III (Post-experimental period)

During this period, all the calves were grazed together on pasture. At the end of this period, LW was obtained. Because of some practical reasons, LW was measured at same date (Feb. 1, 1984) rather than at same age .

Liveweight gain was measured over this period (ranging from 74 to 103 days) in order to estimate the long term effect of treatments on calf performance. Therefore, the actual age at that stage varied from 21 to 25 weeks of age, (average 23 weeks old).

## 2.2 EXPERIMENTAL FOODS

### 2.2.1 Milk

Milk used in the experiment was the whole fresh milk collected each morning from the No.3 Dairy of Massey University prior to commencement of morning feeding . The herd consisted of Friesian, Jersey and Friesian X Jersey cows. The milk was kept at 4°C for the afternoon feeding. The overall milk fat test for the herd in October was 4.4%.

### 2.2.2 Pasture

Fresh pasture was cut daily or every two days from the paddocks on No.3 Dairy . Initially, the harvesting was done by a small rotary lawn mower with this later being replaced by a larger forage harvester mounted on a tractor. There was an obvious visual difference between the herbage harvested by these two machines. The second one cut grass which was much more finely chopped than first one. The of pasture used was predominantly ryegrass and white clover.

### 2.2.3 Water

Initially, water was offered in a bucket throughout the day. Calves were taught to drink from water trough in the individual pen and later were to get water from the water trough.



### 2.3 EXPERIMENTAL ANIMALS

Sixteen Friesian bull calves of 3 weeks of age were used. Half of them were high breeding index (HBI) calves and another half were low breeding index (LBI) calves. They were reared as one group before the experiment. They had had access to leafy pasture besides being offered milk and a small amount of meal.

At the time they entered the experiment, they were blocked according to their LW. Within each block, there were two HBI calves and two LBI calves and they were randomly allocated to each milk treatment.

40 hours fasting was carried out before the start of the experiment. The purpose of it was to obtain empty body weight (EBW) since the calves had had access to pasture before. This procedure is also claimed to minimize the risk of infectious scours (Lawrence and Pearce, 1965). The calf's EBW was used to calculate its empty body weight gain while indoors (EBWG).

Until the experiment was finished, the calves were kept in individual pens. Eight calves were kept in individual metabolism crates for two periods each of 13 days during which digestibility trial and nitrogen balance trial were carried out.

The room where the calves were kept was well ventilated and the temperature was 15 C. The relative humidity was probably high since the room was washed once daily in order to keep it clean. It was illuminated in the daytime.

Any calves that showed signs of scouring or scoured were 1) isolated from other calves; 2) treated with Vytrate (Beecham Veterinary Products, Division of Beecham Ltd); 3) drenched with "Scourban" (Vetc Products Auckland) and 4) stopped feeding for 1-2 days. But no regular drenching with antibiotics was used. During the experimental period, all calves were sprayed once for eliminating lice inhabitation on their skin.

## 2.4 EXPERIMENTAL PROCEDURE

### 2.4.1 Intake

#### 2.4.1.1 Milk

The milk feeding time was 0900 -1000 h and 1500 -1600 h every day. At each of these feedings, calves were fed half of their daily milk allowance. The milk was fed from buckets except for one (No 33) which was suspected to have an incomplete closure of oesophageal groove. This calf was fed by teat-sucking from a bucket.

Teaching the calves to drink from buckets was required for the first few days since before the onset of the experiment, they got their whole milk or other liquid feed through teats.

The milk that could not be finished after 30 min was taken away as milk refusal and weighed. In the afternoon, a small amount of hot water was added to the cold milk(4°C) just taken from the store-room.

#### 2.4.1.2 Herbage

Herbage was offered after the milk was finished or taken away. In order that the calves could eat the herbage ad libitum, the daily herbage allowance was roughly determined by a 20% increase from intake of the previous day. Consideration was given to the estimated DM content of the herbage in question.

The daily herbage allowance was offered twice or even more times daily. The reasons for this were to keep the herbage as fresh as possible and avoid wastage due to spilling if offered too much at one time. About 60% of the daily herbage allowance was offered in the morning feeding. This was because the initial observation showed that calves ate a bigger proportion of daily feed in the daytime.

Throughout the day herbage was available continuously except for about one hour around morning milk feeding. The herbage refusal of the previous day was taken away and weighed before milk was fed. The fresh herbage was offered after milk feeding was finished.

#### 2.4.2 Calf Growth Performance

Weight gain was measured in two ways:

1. Empty body weight gain (EBWG)
2. Liveweight gain (LWG)

##### 2.4.2.1 EBWG Measurement

Empty body weight (EBW) was measured at three points of time in the whole experimental period. They were at:

1. commencement of the experiment. Calves were fasted for 40 hours before weighing (from 1600 h day 1 to 0800 h day 3).
2. weaning time. They were starved for also 40 hours before weighing.
3. end of the indoor experiment. Calves were starved for 48 hours this time due to the increased dry food intake.

The purpose of measuring the EBW was to estimate the growth rate more accurately. But because of the stress that fasting caused on animals it was used as little as possible.

##### 2.4.2.2 LWG Measurement

Liveweight (LW) was measured weekly except during digestibility trial periods. All the measurements were done before the morning feeding in order to minimize the possible error due to different gut fill. Some calves were weighed more frequently (3-4 days) after weaning to estimate the length of the weaning check. Difference method (Bailey *et al*, 1958) was used to calculate the growth rate of the calves.

#### 2.4.3 Apparent Digestibility of the Pasture

Two calves from each group (see section 2.1), a total of eight calves, were involved in two digestion trials. The organization of the trials was as in Table 2.2.

Table 2.2 The Layout of the Digestibility Trials

---

TRIAL	ADAPTION(DAYS)	COLLECTION(DAYS)
I	2	10
II	5	7

---

Trial I was carried out before the calves were weaned whereas trial II was carried out after the calves were weaned (i.e. in Period I & II respectively).

#### 2.4.3.1 The Digestibility of Diet and Pasture before Weaning

The objective of determining digestibility of the diet (milk + pasture) and pasture in this period was to observe the effect of milk feeding level, total feeding level and the genotype of the calves on the calf digestion of feed.

Eight calves of similar age were used. The treatments remained the same except that they were moved from individual pen to metabolism crates. Water was offered in buckets attached to the crates.

The total collection method was used. Faeces were collected daily and bulked over the whole collection period. They were kept at  $-17^{\circ}\text{C}$  before the end of the collection. After the trial, the bulked wet faeces were weighed. After well mixing, two samples of each about 200g were taken for analysis. One was used for DM content determination. Another was freeze-dried and ground for chemical analysis.

#### 2.4.3.2 The Digestibility of Pasture after Weaning

The objective of this trial was to 1) continue the observations on treatment effect on digestibility and 2) compare the differences in digestibility of herbage before and after weaning if any.

The procedure of collection and sampling were similar to those in the digestibility trial in the pre-weaning period (section 2.4.2.1).

#### 2.4.4 Nitrogen Balance

Nitrogen balance trials coincided with the digestibility trials. The same groups of calves were used.

Calf urine was collected daily and weighed. 10% of the daily collection was kept at 4°C. In order to prevent ammonia loss (NH<sub>3</sub>), a small amount (10 - 30 ml) of H<sub>2</sub>SO<sub>4</sub> solution (concentration 2N) was added to the buckets before collection.

At the end of the collection period, samples of urine were taken from the urine kept after it was well stirred for nitrogen and energy analysis.

#### 2.4.5 Analysis of the Food, Faeces and Urine

##### 2.4.5.1 Food

Both milk and pasture were sampled daily. The milk samples of every three days were pooled and kept at 4°C before they were freeze-dried and analysed. The following analyses were carried out on milk samples.

1. the dry matter content of the milk. This was determined by drying the milk sample in a force-drought oven for 24 h at 100°C.
2. nitrogen content by Macro-kjeldahl method.
3. gross energy (GE) content by calorimetric bomb.

The herbage samples were kept at -17°C before they were freeze-dried. After drying, the samples were ground through a 1mm mesh and stored in air-tight glass jars or plastic bottles. The analyses done with herbage samples were:

1. the DM content. This was similar to milk DM content determination except that it was done daily with 2 replicas for herbage samples.
2. nitrogen content
3. GE content
4. ash content
5. in vitro digestibility. It was estimated by cellulase method

(Jones et al , 1973).

Except the DM content, the analyses of herbage were done on weekly basis using standard methods (AOAC, 1975).

#### 2.4.5.2 Faeces and Urine Analysis

The faeces collected in digestibility trials were analysed for the following items:

1. DM content
2. N content
3. GE content
4. Ash content

#### 2.4.5.2 Urine

Urine was analysed for:

1. N content
2. GE content

The analyses on the chemical content of these samples were done in the standard methods (AOAC, 1975).

#### 2.4.5.3 Herbage Refusals

Herbage refusals of the calves were collected and sampled. They were used for DM content determination in order to obtain the DM intake daily. Besides, the herbage refusal samples from calves involved in the digestibility trials were further analysed for in vitro digestibility and ash content in order to estimate the effect of selection during the ingestion process.

### 2.5 STATISTICAL ANALYSIS

The effects of milk feeding level (ML) and breeding index (BI) of the calves upon herbage consumption, weight gain and other parameters of calf performance were investigated by analysis of variance in each period and in the whole experimental period. Regression analysis was

further used to estimate the quantitative relationship between milk intake and herbage consumption, growth performance and some other variables.

The statistical analysis was carried out by using the "REG" program --- a generalized linear models programme (Dept. Animal Science of Massey University).

The following symbols have been used throughout the present thesis to describe the level of significance of differences between means:

\*\*\* Differences significant at the 0.1% level of probability.

\*\* Differences significant at the 1% level of probability.

\* Differences significant at the 5% level of probability.

In a few occasions,  $p < \text{ or } = 0.10$  was used to represent that the differences between means were significant at the 5 to 10% level.

NS Differences not significant.

S.E. Standard error of the means.

## CHAPTER 3

### RESULTS

#### 3.1 ANIMAL HEALTH

In the pre-weaning period (period I), five calves (No.8,14,32,36, 46) were recorded to have scoured on six occasions (No.32 twice). The age at which they scoured varied from 3 to 7 weeks old. Besides stopping the feeding of milk and herbage for 1-2 days, they were treated with "ViTrat Veterinary Products, Division of Beecham Ltd) and drenched with "Scourban" (Vetc Products, Auckland). All of them recovered in less than 3 days. There was an indication that LBI calves were more susceptible to scouring than HBI calves (5 v 1) ( $0.1 > p > 0.05$ ). Calf No.33 was observed to have a grossly distended abdomen on the left side in the second week of the experiment (approximately 4.5 weeks old). This was suspected to be the result of incomplete closure of the oesophageal groove so that the milk got into the rumen. After changing the milk feeding procedure for this calf from drinking directly from a bucket to sucking from a rubber teat, the phenomenon disappeared. This seemed to support the suspicion as to the cause. The calf health situation after weaning was satisfactory. There were no cases of disease or death recorded prior to the time the calves reached 21-25 weeks of age (Feb. 1, 1984).

#### 3.2 FEED QUALITY

##### 3.2.1 Milk

The whole milk used in the experiment was obtained from a herd of mainly Friesian and Friesian X Jersey cross cows. The milk fat test for the whole herd over one month in the experimental period (Sept., 1983) was 4.4%.

The mean values for the composition of the milk samples taken during the experimental period are listed in Table 3.1.



Table 3.1 Milk Composition

FAT%	N%	PROTEIN%	GE(KJ/KgDM)	DE(KJ/kgDM)	DM%
4.83 <sub>+0.22</sub>	0.52 <sub>+0.01</sub>	3.31 <sub>+0.13</sub>	23.53 <sub>+0.48</sub>	22.35	13.95 <sub>+0.35</sub>

\*DE was obtained by assuming that the digestibility of milk energy is 95% (Blaxter, 1962, Brookes & Davey, 1977).

3.2.2 Herbage

The pasture used in the experiment was predominantly ryegrass and white clover. The quality of the herbage was assessed in the following two ways.

(1) Chemical analysis

The mean values of the chemical composition of the herbage samples from the experiment are shown in Table 3.2.

Table 3.2 Composition of Herbage

N%	ASH%	GE(KJ/KgDM)	DM%
3.51 <sub>+0.14</sub>	14.30 <sub>+1.36</sub>	17.92 <sub>+0.82</sub>	16.85 <sub>+0.29</sub>

(2) In vitro and in vivo DOM of the herbage

The quality of the herbage was also assessed in terms of their in vitro and in vivo digestibility.

The in vitro DOMD of herbage samples and the change with time are shown in Fig.3.1. The mean in vitro DOMD of herbage was 78.93<sub>+1.33</sub>%.

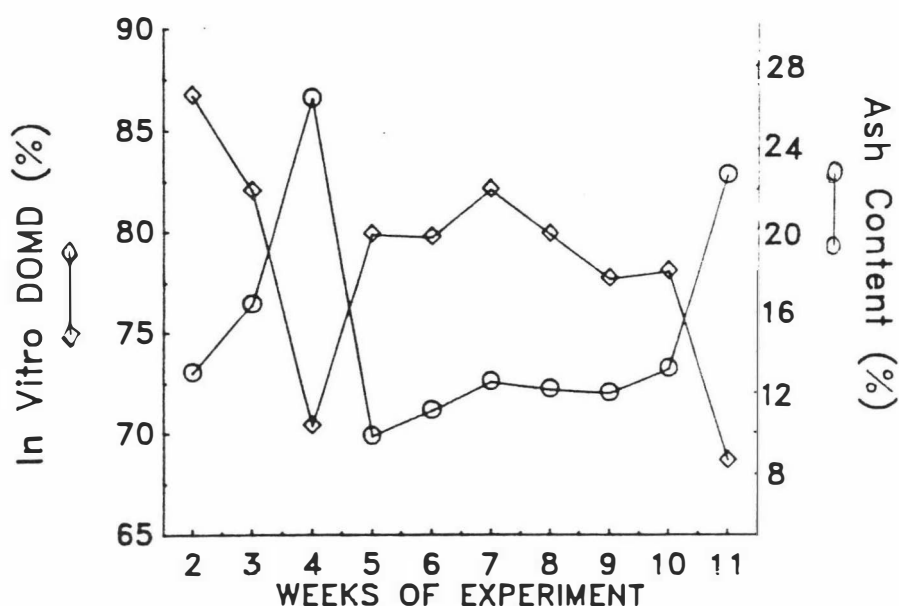


FIG.3.1 The Variation of in vitro DOMD and Ash Content over Experiment

The in vivo DOM of the herbage was estimated by using two groups of four calves (G1 and G2, including calves of two BI and receiving two milk feeding levels), both before and after weaning (see section 2.4.2 ). These results and the in vitro DOMD of herbage for the same period are listed in Table 3.3.

Table 3.3 In vivo and in vitro Digestibility of Herbage OM(%)

TIME	GROUP*	<u>in vivo</u> DOM**	<u>in vitro</u> DOMD
BEFORE WEANING (PERIOD I)	G1	74.78 $\pm$ 5.57	80.50
	G2	74.88 $\pm$ 4.31	81.86
AFTER WEANING (PERIOD II)	G1	78.32 $\pm$ 2.05	82.10
	G2	77.64 $\pm$ 0.72	78.64

\* G1 group I including calves No. 6,8,10,13

G2 group II including calves No. 32,33,36,42

(these two groups of calves were chosen because of the similarity of their age within groups)

\*\* in vivo DOM of the herbage in pre-weaning period (period I) was obtained by deduction method (see section 3.5.1).

Because there were not enough replicates, it was not possible to statistically compare the difference between in vivo and in vitro digestibility of the herbage. It appeared that in vitro DOMD tended to over-estimate the DOM of herbage for calves for about 1 to 7 units in the present experiment.

### 3.3 FEED INTAKE

#### 3.3.1 Milk Intake

The milk feeding level was a treatment variable in the experiment. The two levels used in the experiment were 6.0 l/calf/d (HM) and 4.5 l/calf/d (LM). The milk feeding period was 31±2 days. Calves were weaned in two days at the age of 7.5 weeks old. The actual milk intake per day and over period I is as shown in Table 3.4.

Table 3.4 Calf Milk Consumption in Period I

TREATMENT	HM	LM	S.E.	SIGNIFICANCE
DAILY MILK INTAKE	5.83	4.48	0.18	**
TOTAL MILK CONSUMPTION IN PERIOD I	195.25	148.56	6.42	**

Calves on HM treatment received significantly more milk per day or throughout the whole experimental period. However, there were more instances when HM calves could not finish the amount of milk offered. LM calves finished nearly 100% of the milk allowance whereas HM calves on average finished 97% of the milk offered.

3.3.2 Herbage Consumption

Herbage consumption was strongly influenced by milk feeding level and calf maturity represented by either age or LW. The relationship between calf age and herbage consumption is shown in Fig. 3.2.

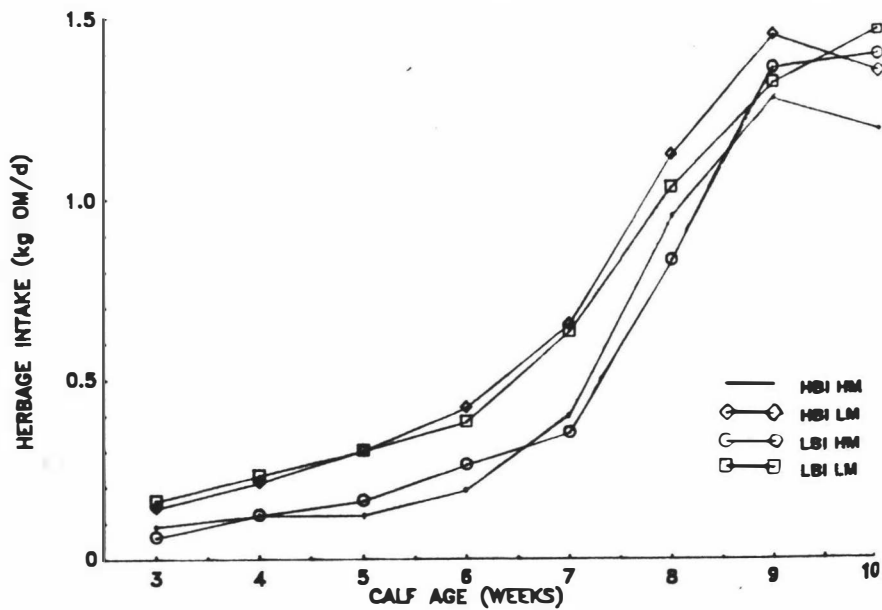


FIG. 3.2 The Relationship of Calf Herbage Intake and Age

Table 3.5 The Comparison of HM & LM Calves for Daily Herbage Intake  
(Kg OM/D)

AGE(WEEKS)	HM	LM	S.E.	SIGNIFICANCE
4	0.08 <sub>+0.016</sub>	0.15 <sub>+0.021</sub>	0.016	*
5	0.11 <sub>+0.020</sub>	0.22 <sub>+0.022</sub>	0.019	**
6	0.14 <sub>+0.030</sub>	0.30 <sub>+0.025</sub>	0.028	**
7	0.22 <sub>+0.045</sub>	0.40 <sub>+0.049</sub>	0.039	*
8	0.37 <sub>+0.050</sub>	0.64 <sub>+0.084</sub>	0.058	*
9	0.92 <sub>+0.051</sub>	1.11 <sub>+0.049</sub>	0.043	*
10	1.32 <sub>+0.077</sub>	1.39 <sub>+0.041</sub>	0.043	NS
Regression Coefficient				
(Kg OM/wk)	0.20 <sub>+0.016</sub>	0.21 <sub>+0.013</sub>	0.011	NS

There was no significant difference in the rate of herbage consumption development (i.e. the slope of the line, b value) ( $p>0.05$ ) between milk treatments, but LM calves consistently ate more herbage than HM calves between 4 and 9 weeks of age (Table 3.5).

The intake of herbage at various stages of the experiment and the rate of herbage intake development were not significantly different between HBI and LBI calves (Fig. 3.2). Detailed results of herbage intake in each period are described in the following sections.

### 3.3.2.1 Herbage Consumption before Weaning (Period I)

Milk feeding level had a negative effect on the herbage intake of the calves ( $p<0.01$ ) (Table 3.5). HM calves ate on average 0.16 Kg less herbage OM/d in this period than LM calves. On the other hand, they ate on average of 30 g more OM/d in total diet than LM calves. The correlation coefficient between milk intake and daily herbage organic matter intake (HOMI) for individual calves in this period was -0.68 ( $p<0.01$ ). The relationship was as follows (Fig.3.3):

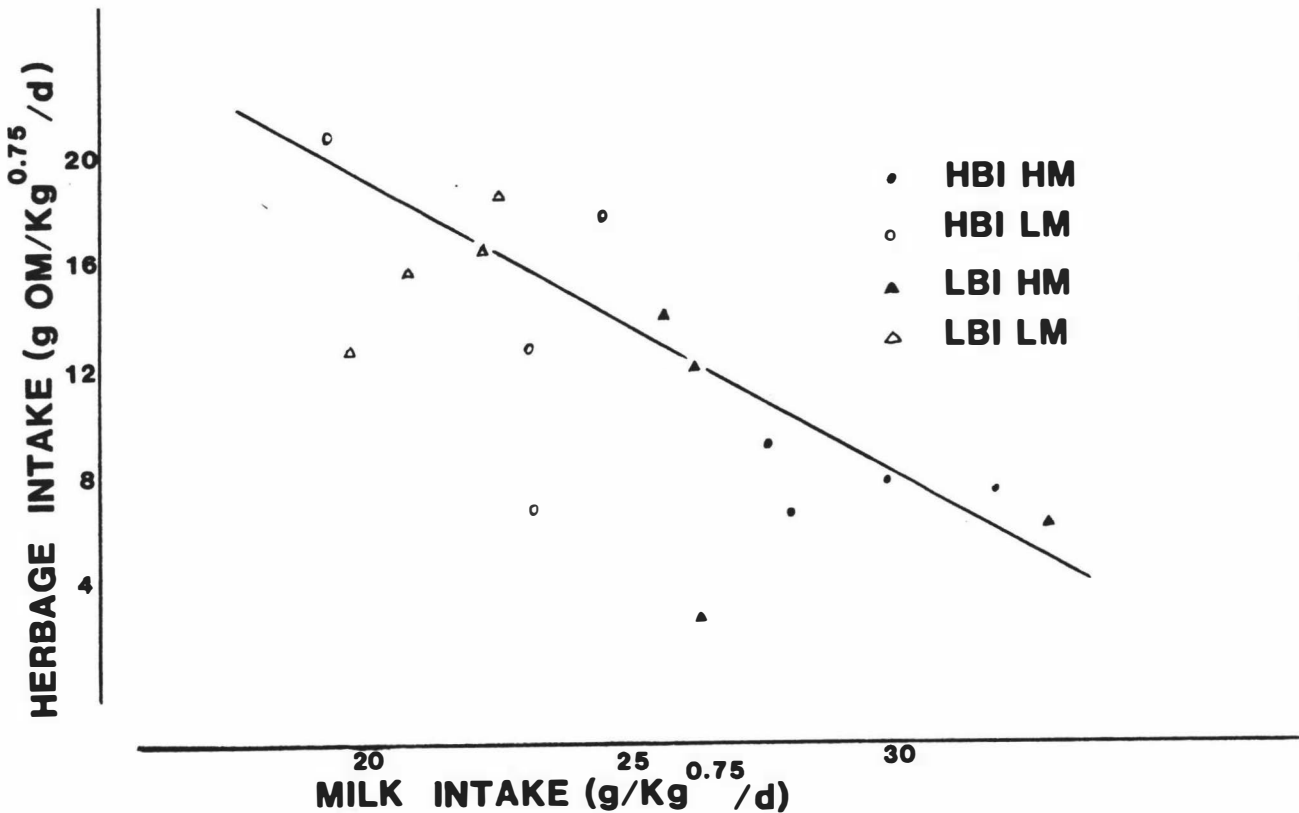


FIG. 3.3 The Relationship between Milk Intake and HOMI in Period I

$$Y = -0.110(+0.032)X + 1.096(+0.165) \quad R^2 = 0.46 \quad p<0.01$$

where Y is HOMI Kg /calf/d and X is milk intake Kg/calf/d  
So, the replacement rate was 0.11 Kg herbage OM/Kg milk.

Measured as milk dry matter, the relation was as follows:

$$Y = -0.819(+0.236)X + 1.096(+0.165) \quad R^2 = 0.46 \quad p < 0.01$$

where Y is herbage intake OM Kg/d and X is milk intake DM Kg/d

The effect of calf BI was not significant ( $p > 0.05$ ) and there was no interaction between milk feeding level and BI ( $p > 0.05$ ).

3.3.2.2 Herbage Consumption after Weaning (Period II)

The daily herbage organic matter consumption in this period was negatively correlated with the milk intake in the previous period ( $r = -0.63$ ,  $p < 0.01$ ) (Fig 3.4). It was positively correlated with the HOMI in period I ( $r = 0.84$ ,  $p < 0.0001$ ) (Fig. 3.5). The correlation coefficients were greater for LBI calves ( $r = 0.96$ ,  $p < 0.001$ ) and for HM calves ( $r = 0.96$ ,  $p < 0.0001$ ) than for HBI and LM calves. But it was not significant for LM calves ( $p > 0.05$ ).

The LW at the commencement of the experiment was significantly correlated ( $r = 0.62$ ,  $p < 0.05$ ) with the herbage intake in the final week of the experiment (aged 9.5-10.5 weeks) but not with those in other weeks. Within BI groups, the correlation was significant only for HBI calves ( $r = 0.82$ ,  $p < 0.05$ ). On the other hand, the herbage intake of LBI calves in this week was significantly ( $r = 0.82$ ,  $p < 0.05$ ) affected by herbage intake in the pre-weaning period. This was not true for HBI calves ( $p > 0.05$ ).

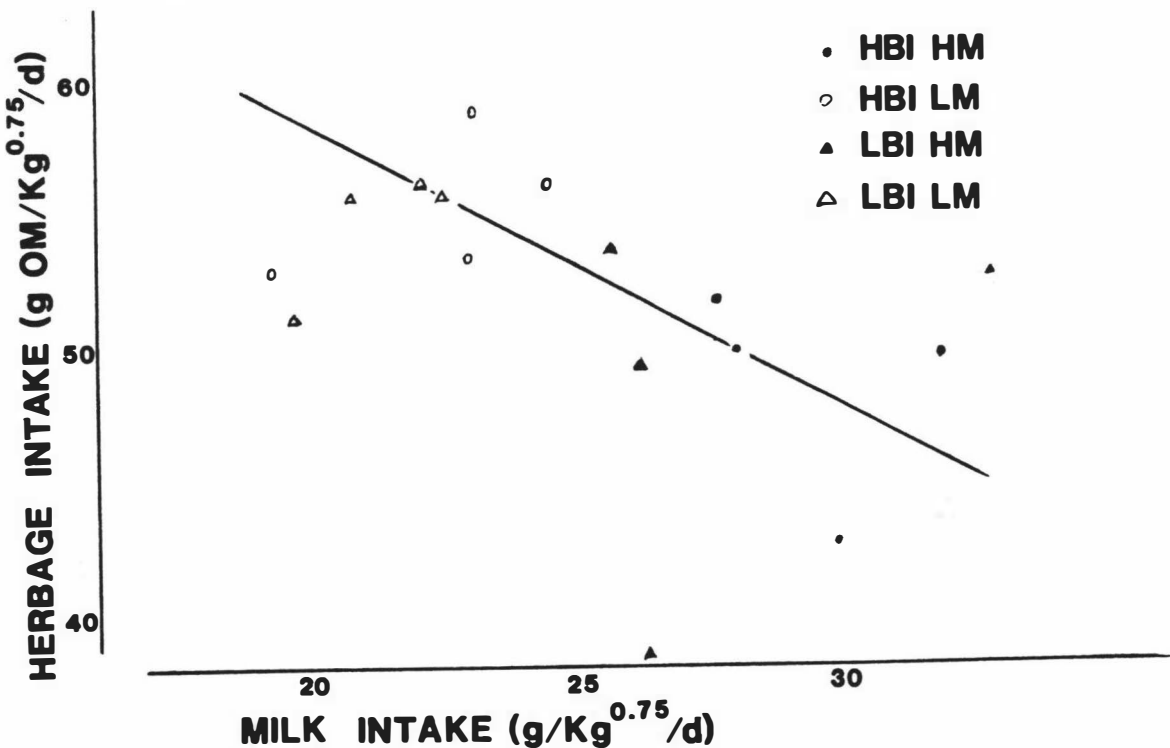


FIG. 3.4 The Relationship between Milk Intake in Period I

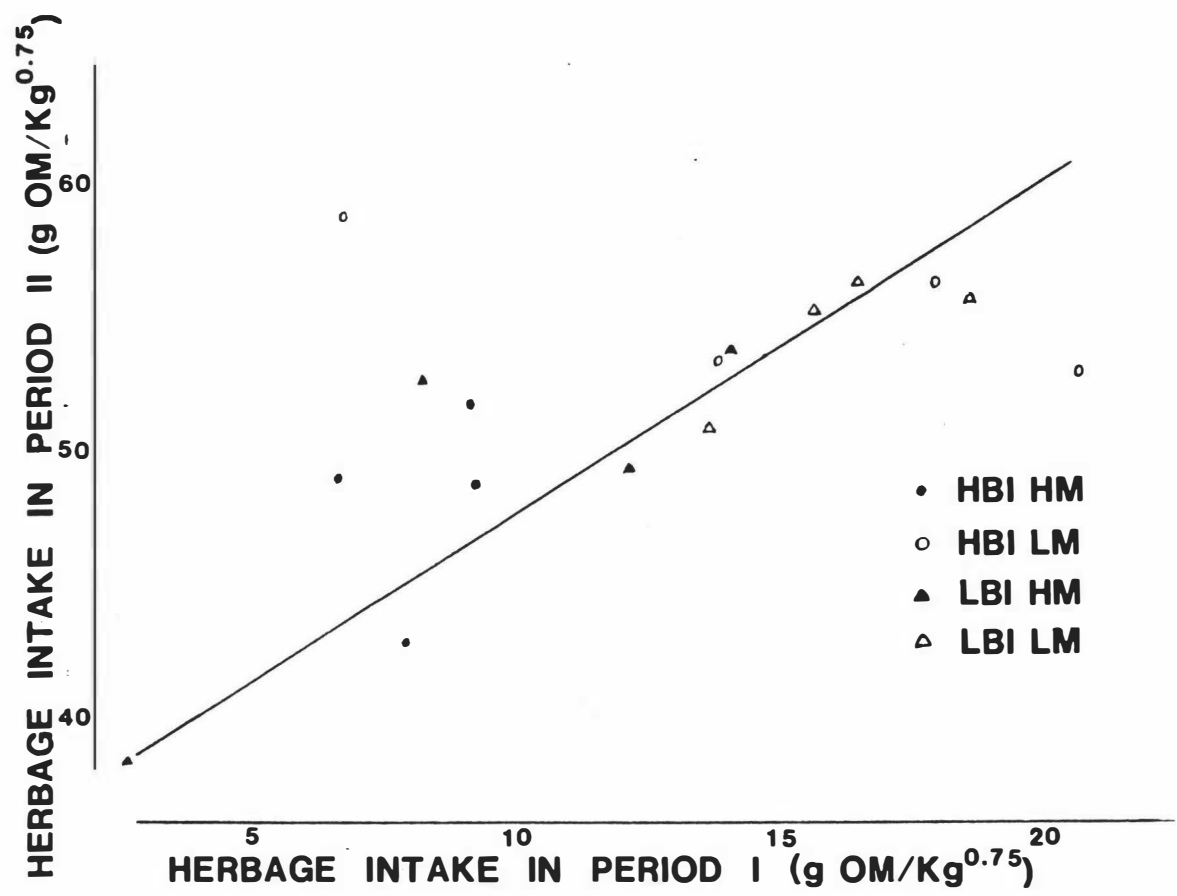


FIG. 3.5 The Relationship between HOMI before and after Weaning

3.3.2.3 Selection of Herbage by Calf during Ingestion Process

Comparison of herbage quality (in vitro DOMD%) showed that selection of herbage during the ingestion process may occur. The higher ash content of pasture refused also suggests that the animals avoided soil contaminated pasture. Statistical analysis showed that the differences in in vitro DOMD and ash content between the herbage offered and refused were significant (Table 3.6).

Table 3.6 Comparison of Herbage Offered and Refused

HERBAGE	OFFERED	REFUSED	S.E.	SIGNIFICANCE
ASH%	12.15	18.55	1.81	p<0.10
<u>IN VITRO</u> DOMD%	80.77	71.67	0.76	***

### 3.4 CALF GROWTH PERFORMANCE AND LW CHANGE

The calf LW changes throughout the experiment and post-experimental period are shown in Fig.3.6 and Table 3.7.

The calf's weaning LW and the LW at the end of the experiment (10.5 weeks of age) after adjusting for initial LW and herbage intake were significantly ( $p < 0.05$ ) affected by the milk feeding level in preweaning period. But the LW at 21-25 weeks of age was not affected by the milk feeding level even if the effects of initial LW, herbage intake and calf age at weighing upon the LW were adjusted. At 21 - 25 weeks of age, HM calves of HBI appeared to be lighter than other calves (119.5 v 130.0 Kg) but this was not significant ( $p > 0.05$ ).

Table 3.7 Calf LW at Different Stages of the Experiment (Kg)\*

TREATMENT BI	HM		LM		S.E.	Signi- ficance
	HBI	LBI	HBI	LBI		
AT THE START OF THE EXPERIMENT	47.44 (46.66)	51.08 (49.13)	50.13 (48.00)	52.31 (50.25)	1.56	NS
WEANING WEIGHT (7.5 WKS OLD)	65.59 (63.19)	69.19 (67.31)	66.31 (62.25)	71.06 (65.94)	1.66	NS
FINAL LIVE WEIGHT (21-25 WKS OLD)	119.50	129.00	128.50	131.50	4.56	NS

\* values in brackets are empty body weight (EBW) at the same stage

The important factors which apparently influenced the calf LW at 21 - 25 weeks of age are:

1. the age at the time of weighing (1, Feb. 1984) ( $r = 0.67$ ,  $p < 0.01$ ),
2. LW at 3 weeks of age ( $r = 0.55$ ,  $p < 0.05$ ),
3. herbage intake at 10 weeks of age (final week in the indoor feeding period) ( $r = 0.78$ ,  $p < 0.01$ ).



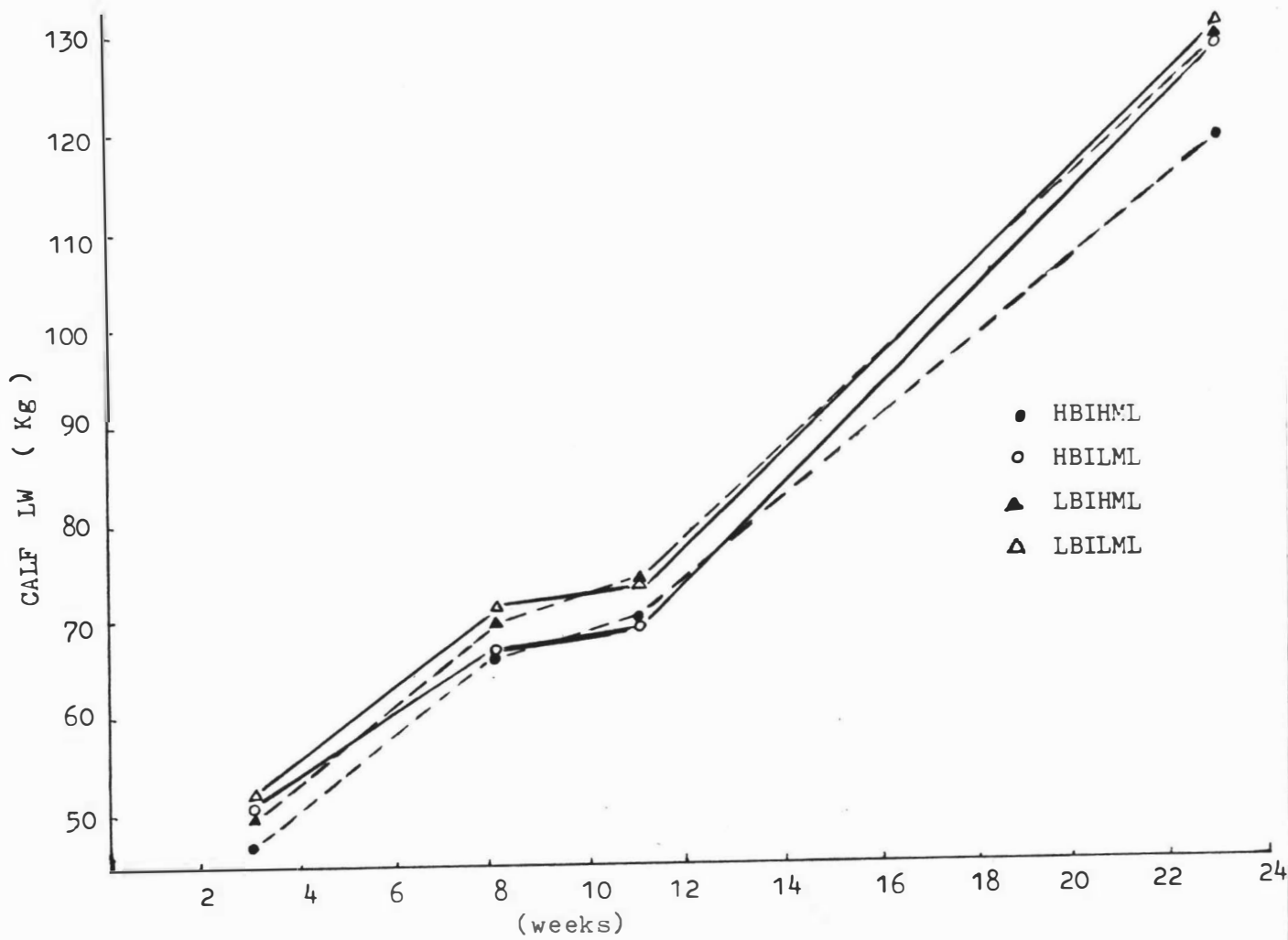


FIG. 3.6 The Relationship between Calf LW and Age

LW at 21 - 25 weeks of age can be calculated from the following equation:

$$Y = 0.63(+0.45)X_1 + 0.57(+0.24)X_2 + 0.54(+0.17)X_3 - 71.77(+36.84)$$

$$R^2 = 0.77 \quad p < 0.001$$

where Y is LW of the calves at 22 - 25 weeks of age

$X_1$  is LW at 3 weeks of age

$X_2$  is calf age in days

$X_3$  is herbage intake in week 10 (OM Kg/d)

The mean growth rates of calves received two milk treatments and of two BI groups from 3 to 21 - 25 weeks old and in different periods are shown in Tables 3.8 and 3.9.

Table 3.8 The Growth Rate of Calves Receiving Two Milk Treatments

TREATMENT	HM	LM	S.E.	SIGNIFICANCE
PERIOD I (3 TO 7.5 WKS)	0.55	0.44	0.03	*
PERIOD II (7.5 TO 10.5 WKS)	0.21	0.31	0.03	NS
PERIOD III (10.5 TO 22-25 WKS)	0.59	0.63	0.03	NS
WHOLE PERIOD (3 TO 22-25 WKS)	0.52	0.53	0.02	NS

Table 3.9 The Growth Rate of HBI and LBI Calves

BI	HBI	LBI	S.E.	SIGNIFICANCE
PERIOD I	0.48	0.51	0.03	NS
PERIOD II	0.23	0.30	0.03	NS
PERIOD III	0.60	0.61	0.03	NS
WHOLE PERIOD	0.52	0.54	0.02	NS

The calf growth performance over the whole observatory period (from 3 to 21 - 25 weeks of age) was not significantly different between calves fed high and low milk level or the two BI groups of the

calves. There was also no significant interaction (Appendix-one, Table 1).

The growth rate over the whole period was significantly correlated with the growth rate of the calves in period III (from 10.5 to 21 - 25 weeks of age).

$$Y = 0.679(+0.060)X + 0.116(+0.037) \quad R^2 = 0.90 \quad p < 0.0001$$

where Y is LWG over the whole period from 3 to 21 - 25 weeks of age

X is LWG from 10.5 to 21 - 25 weeks of age

But the growth rate in period I, during which HM calves grew significantly faster than LM calves (see section 3.4.1), had no significant effect on the growth rate over the whole period ( $p > 0.05$ ).

Herbage organic matter intake (HOMI) before weaning and after weaning tended to be positively associated with the calf growth rate over the whole observatory period (from 3 to 21 - 25 weeks of age) ( $r = 0.46$ ,  $p = 0.07$  and  $r = 0.44$ ,  $p = 0.09$  respectively). Within milk treatments, HM calves' growth rate over the whole period was significantly ( $p < 0.05$ ) correlated with the HOMI in post-weaning period. But for LM calves, their growth rate was not correlated with the herbage intake in post-weaning period.

The calves' growth performance appeared to be affected by the stress resulted from caging during the digestion trial periods. The eight calves which were involved into the digestion trials grew significantly slower than other eight calves ( $0.37$  v  $0.45$  Kg/d,  $p < 0.05$ ) (over the two periods of the experiment).

Calf growth performance in each period is described in detail in the following sections.

3.4.1 Calf Growth Performance in Period I (Pre-weaning Period)

The mean live weight of the calves in each treatment group at the commencement of this period (average 21<sub>+1</sub> days old) was listed in Table 3.6. There was no significant difference between them (p>0.05).

3.4.1.1 The Relationship between Milk Plus Herbage Intake and Calf Growth Rate and the Effect of Breeding Index (BI)

Calf growth rate in this period was significantly affected by milk feeding level (see Appendix-one,Table 2). The calves which received 6.0 l milk /d (HM) grew 25% faster than calves which received 4.5 l milk/d (Table 3.8). The correlation coefficient between growth rate and daily milk intake was 0.60 (p<0.05).

HOMI in this period was another factor significantly influencing the growth rate of the individual calves within milk treatments (Table 3.10).

Table 3.10 Regression Equations Relating EBWG to HOMI in Period I

EQUATION	R <sup>2</sup>	SIGNIFICANCE
HM CALVES		
Y = 0.909( <u>+0.359</u> )X + 0.132( <u>+0.168</u> )	0.52	*
LM CALVES		
Y = 0.791( <u>+0.138</u> )X + 0.035( <u>+0.084</u> )	0.86	**
Where Y is EBWG Kg/Calf/d and X is HOMI Kg/Calf/d		

The multiple regression analysis showed that the growth rate in period I was largely determined by both milk and herbage intake.

EBWG (Kg/calf/d) = 1.69(+0.33)X<sub>1</sub> + 0.89(+0.21)X<sub>2</sub> -0.85(+0.26)

R<sup>2</sup> = 0.68                      p<0.001

where X<sub>1</sub> is milk intake Kg/calf/d

X<sub>2</sub> is herbage organic matter intake Kg/calf/d

The mean weaning weight is shown in Table 3.7. There was no significant difference in weaning weight between calves fed high and low levels of milk or calves in the different BI groups (see Appendix-one,Table 3).

3.4.1.2 The Relationship between ME Intake and Calf Growth Rate in Period I

In calculating the ME intake of the calves in the present experiment, the ME value of milk was determined to be 2.9 MJME/Kg whole milk from its gross energy content (see Table 3.1) on the basis of 94.3% digestibility obtained by extrapolation method (see section 3.5.1) and 94% metabolizability of DE. The ME of herbage was assumed to be 11.5 MJME/Kg DM although in reality it probably varied from day to day (see section 3.5.1). The total ME intake (MEI) was closely associated with the calf growth rate (Table 3.11 and Fig. 3.7).

Table 3.11 The Regression Equations Relating EBWG to MEI

EQUATION	R <sup>2</sup>	SIGNIFICANCE
HM CALVES		
Y = 0.104(+0.033)X - 1.524(+0.665)	0.62	*
LM CALVES		
Y = 0.049(+0.017)X - 0.441(+0.303)	0.58	*
Where Y is EBWG Kg/CALF/D and X is MEI MJ/CALF/D		

The b values of the equations, which represent the responses of calves in growth rate to the increase of one MJ of ME intake, were different between HM calves and LM calves (Fig. 3.7). The HM calves grew faster ( $p < 0.10$ ) in response to an increase of one MJME intake than LM calves (0.104 v 0.049 Kg for HM and LM calves respectively).

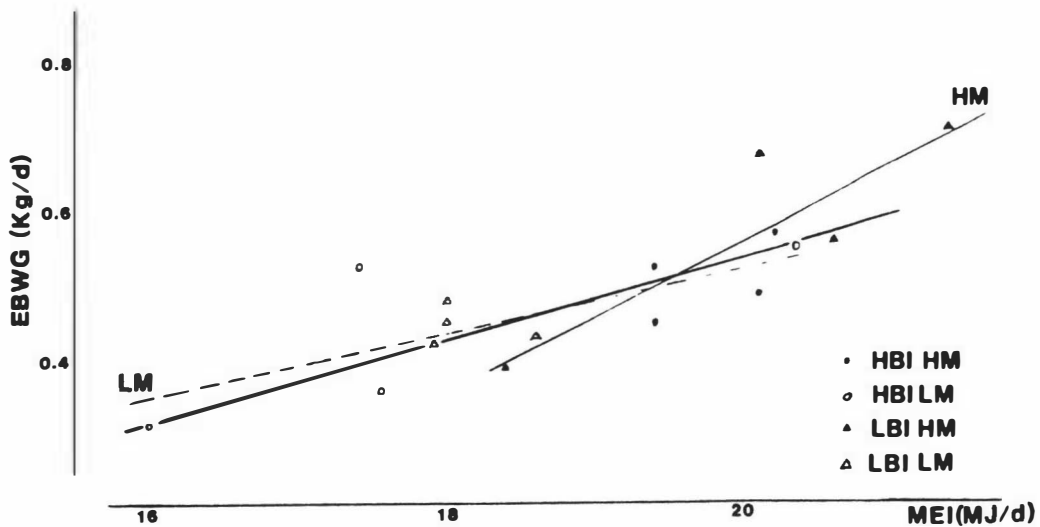


FIG. 3.7 The Relationship between ME Intake and Growth Rate

#### 3.4.2 Calf Growth Performance during 3 Weeks Following Weaning (Period II)

Calf growth rate in this period was relatively poor for all calves and not significantly affected by BI of the calves or milk feeding level before weaning (Tables 3.8, 3.9 and Appendix-one, Table 4).

The individual calf growth rate in this period was positively related to their HOMI in this period ( $r = 0.48$ ,  $p = 0.06$ ).

#### 3.4.3 Calf Growth Performance in Period III

The effects of milk feeding level before weaning and BI of the calves on calf growth rate during the post-experimental grazing period were not significant (Tables 3.8, 3.9 and Appendix-one, Table 5).

Herbage organic matter intakes in period I and II had a positive

effect on the growth rate of the calves in period III ( $r=0.42$ ,  $p=0.10$  and  $r=0.41$ ,  $p=0.11$ , respectively). The HOMI in the last week of indoor feeding stage (age 9.5 to 10.5 weeks) also had a significant effect on calf growth rate in this period ( $p<0.05$ ). The regression equation is as following:

$$Y = 0.389(+0.156)X + 0.081(+0.213) \quad R^2 = 0.31 \quad p<0.05$$

where Y is EBWG Kg/calf/d

X is HOMI at the 9.5 to 10.5 weeks of age

### 3.5 DIGESTION AND NITROGEN METABOLISM

#### 3.5.1 Digestibility of the Milk and Herbage in Period I

The digestibility of the whole diet was determined by the total collection method and mean values are shown in Table 3.12.

Table 3.12 DOM of the Whole Diet in Period I (%)

TREATMENT	HBI	LBI	MEAN+S.E.
HM	91.32	90.70	91.01 $\pm$ 1.03
LM	86.44	87.73	87.08 $\pm$ 0.65**

The effect of milk feeding level on DOM of the diet was significant ( $p<0.01$ ). The diet of the HM calves had a significantly higher DOM value than that of LM calves (see Appendix-one, Table 6).

The DOM of the herbage ingested in pre-weaning period was determined by the following two ways:

#### 1) Deduction method:

As in Byford's (1974) and Preston et al's (1957) experiments, the digestibility determinations in the present study were calculated on a

one day 'lag' basis, i.e. the faeces were collected 24h after the particular day's food was fed. The digestibility of the milk organic matter is assumed to be constant at 95% (Blaxter, 1962). If the digestibility of milk organic matter is assumed to be constant, the digestibility of the non-milk part of the diet, herbage in the present experiment, can be calculated by the following equation:

$$\text{DOM of the herbage\%} = \frac{\text{HOMI} - (\text{OMf} - \text{OMf(m)})}{\text{HOMI}} \times 100$$

where HOMI is Herbage organic matter intake Kg/head/d  
OMf is the OM in the faeces  
OMf(m) is the OM in the faeces from milk OM digestion

Table 3.13 listed the DOM of herbage calculated in this way. The effects of milk intake level and BI of the calves on DOM of the herbage obtained by this way were not significant (Table 3.13).

Table 3.13 "Estimated" DOM of Herbage in Pre-weaning Period

TREATMENT	HBI	LBI	MEAN+S.E.
HM	77.75	73.50	75.86(+5.75)
LM	68.05	80.00	74.03(+1.73)

But since the milk intake was a big proportion of the whole diet (varying from 55 to 95% in present experiment), the small differences in milk digestibility, which is likely to occur in actual situations, will result in much bigger variation in herbage digestibility calculated in this way. For example, in present experiment, one unit difference in digestibility of milk resulted in 4 units difference in herbage digestibility.



2) Regression method

The digestibility of milk is generally higher than that of herbage or other solid feed in calves (Blaxter, 1962). Therefore, as the proportion of milk organic matter in the whole diet increases, the digestibility of the diet should increase. Assuming that the digestibility of both milk and herbage does not vary with milk intake change or herbage intake change, then the digestibility of the diet is linearly related to milk intake level. Plotting digestibility of the diet to the proportion of milk OM in the diet, the following equation was obtained.

$$Y = 0.154(\pm 0.06)X + 78.9(\pm 4.2) \qquad R^2 = 0.57 \qquad p < 0.05$$

where Y is the digestibility of the diet OM (%)

X is the proportion of milk OM in diet (%).

From the extrapolation to zero herbage intake, the digestibility of milk was 94.3%. By same way, the digestibility of herbage can be calculated. It was 78.9%.

3.5.2 Herbage Digestibility after Weaning (Period II)

The mean DOM of herbage for the four groups of calves in this period are in Table 3.14. The differences in DOM are not significant between either two milk feeding levels or two BI groups (see Appendix-one, Table 7).

Table 3.14 DOM of Herbage in Post-weaning Period (Period II)

TREATMENT	HBI	LBI	MEAN±S.E.
HM	78.21	80.88	79.54(±1.53)
LM	76.16	76.67	76.42(±0.91)

Within the whole group of calves, the relationship between DOM of herbage determined by deduction before weaning (period I) and after weaning (period II) was not significant ( $p > 0.05$ ). However, DOM of herbage in this period was closely correlated with the herbage organic matter intake (HOMI) in period I (pre-weaning period) ( $r = 0.81$ ,  $p < 0.05$ ) and period II ( $r = -0.70$ ,  $p = 0.05$ ). Calves with a higher HOMI in pre-weaning period have a higher DOM value in this period. But the intake in the period II had a negative effect on herbage digestibility. Body weight also had a positive effect on herbage DOM of the calves in this period. A strong correlation was observed between calf LW at the commencement of the experiment (3 weeks of age) and DOM of herbage in this period ( $r = 0.89$ ,  $p < 0.01$ ). Calf weight at the end of the period also has a significant effect on herbage digestibility ( $r = 0.71$ ,  $p = 0.05$ ). It appeared that the calves with a heavier body weight had a higher ability to digest herbage ingested.

### 3.5.3 Nitrogen Metabolism of the Calves

#### 3.5.3.1 Pre-weaning Period (Period I)

A summary of the N balance data obtained from the digestibility trial on 8 calves during pre-weaning period is presented in Table 3.15.

The significant difference in nitrogen intake from milk resulted in significant difference in apparent digestibility of nitrogen ( $p < 0.05$ ). However, there were no significant differences in other parameters of nitrogen metabolism between either milk feeding levels or BI groups.

Table 3.15 Comparisons of Some Parameters of Nitrogen Metabolism  
in Period I

g N/Kg <sup>0.75</sup> /d	HM	LM	MEAN+S.E.		HBI	LBI	MEAN+S.E.	
TOTAL N INTAKE	1.79	1.61	1.70(+0.13)	NS	1.67	1.72	1.70(+0.14)	NS
MILK N INTAKE	1.39	0.97	1.18(+0.06)	***	1.26	1.10	1.18(+0.10)	NS
HER. N INTAKE	0.42	0.64	0.53(+0.11)	NS	0.43	0.63	0.53(+0.11)	NS
DN(%) <sup>1</sup>	86.5	83.2	84.8(+0.87)	*	84.9	84.8	84.8(+0.87)	NS
DN INTAKE	1.55	1.33	1.44(+0.11)	NS	1.42	1.46	1.44(+0.12)	NS
UN <sup>2</sup>	0.88	0.85	0.87(+0.05)	NS	0.95	0.79	0.87(+0.05)	NS
NR <sup>3</sup>	0.65	0.53	0.59(+0.13)	NS	0.45	0.72	0.59(+0.12)	NS

<sup>1</sup> DN% is apparent digestibility of diet nitrogen

<sup>2</sup> UN is the urine N

<sup>3</sup> NR is nitrogen retention

Nitrogen retention was positively correlated with the total nitrogen intake (r = 0.81, p<0.05) and the apparently digestible nitrogen intake(r = 0.83, p<0.05).

$$NR \text{ (g N/calf/d)} = 0.75(\pm 0.23)X - 1.56(\pm 0.89)$$

$$R^2 = 0.65 \qquad p < 0.05$$

where X is NI (g N/calf/d), or

$$NR \text{ (g N/calf/d)} = 0.89(\pm 0.25)X - 1.56(\pm 0.82)$$

$$R^2 = 0.68 \qquad p < 0.05$$

where X is DNI (g N/calf/d)

### 3.5.3.2 Post-weaning Period (Period II)

There were no significant differences in the parameters of nitrogen metabolism between calves fed high or low level milk and calves of HBI or LBI (Table 3.16).

Table 3.16 Comparisons of Some Parameters of Nitrogen Metabolism in Period II

$\text{gN/Kg}^{0.75}/\text{D}$	HM	LM	MEAN $\pm$ S.E.		HBI	LBI	MEAN $\pm$ S.E.	
TOTAL N INTAKE	1.61	1.83	1.72( $\pm$ 0.05)	NS	1.71	1.73	1.72( $\pm$ 0.07)	NS
DN(%)	76.8	72.1	74.4( $\pm$ 1.68)	NS	74.0	74.9	74.4( $\pm$ 1.68)	NS
DN INTAKE	1.28	1.36	1.32( $\pm$ 0.04)	NS	1.31	1.33	1.32( $\pm$ 0.04)	NS
UN	0.71	0.80	0.76( $\pm$ 0.03)	NS	0.76	0.75	0.76( $\pm$ 0.04)	NS
NR	0.65	0.62	0.63( $\pm$ 0.03)	NS	0.61	0.66	0.63( $\pm$ 0.03)	NS

Nitrogen retention was positively correlated with the nitrogen intake in this period ( $r = 0.78$ ,  $p < 0.05$ ).

The relationship obtained from the pooled data (two balance periods each with 8 calves involved) between nitrogen retention (NR) and nitrogen intake (NI) is significant (measured as g/calf/d or  $\text{g/Kg}^{0.75}/\text{d}$ ). The linear equations are as follows:

$$(1) \text{NR}(\text{gN/head/d}) = 0.359(\pm 0.122)X - 2.175(\pm 5.724)$$

$$R^2 = 0.38 \quad p < 0.05$$

$$(2) \text{NR}(\text{gN/Kg}^{0.75}/\text{d}) = 0.399(\pm 0.142)X - 0.171(\pm 0.283)$$

$$R^2 = 0.36 \quad p < 0.05$$

where X is NI g N/calf/d for (1) and NI g N/ $\text{Kg}^{0.75}/\text{d}$  for (2).

CHAPTER 4

DISCUSSION

4.1 CALF FOOD CONSUMPTION

The results of the present experiment showed that feeding a high level of milk (HM) depressed the intake of pasture offered to the young calves in the pre-weaning period and for a few weeks after weaning. These results are in agreement with those of Baker *et al.* (1976), Baker & Barker (1977) and Hodgson (1971e) with calves and Walker & Hunt (1981) and Doney *et al.* (1984) with lambs. Regardless of other factors influencing the quantitative relations between solid and liquid food intake, which will be discussed later, the replacement of herbage organic matter for milk dry matter was 0.11g OM/g milk (or 0.82g OM/g milk DM) in the pre-weaning period (4.5 weeks, from 3 to 7.5 weeks of age). In terms of digestible energy value, the DE intake of extra herbage consumed in the pre-weaning period by the calves receiving the low level of milk treatment (LM) only compensated for about 50% of the difference in milk energy intake between the two treatment groups during the pre-weaning period (see Fig. 4.1).

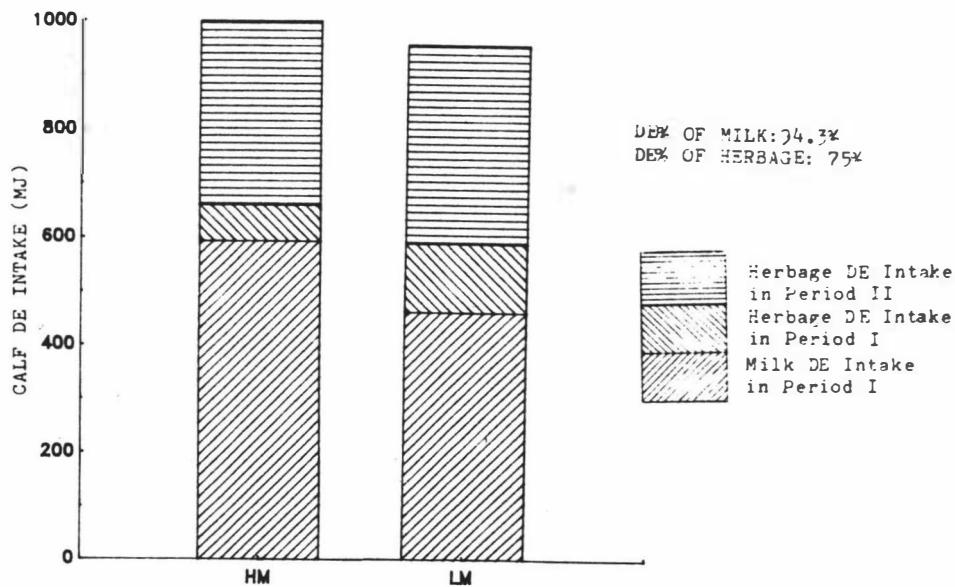


FIG. 4.1 The DE Intake of Calves in Period I and II

But considering from the whole experimental period, the intake of herbage compensated for about 70% of the DE intake difference between HM and LM calves (see Fig. 4.1). The difference in DE intake was only 5% of the total DE intake. The total DE intake of calves was similar for two groups of calves.

A comparison of the replacement rates with those from other experiments (Table 4.1) suggests that such quantitative comparisons can only be valid when the conditions of the experiments are similar since there are other factors influencing the replacement rate.

Table 4.1 Comparisons of Solid Food Replacement for Milk  
(g herbage OM/g milk OM)

AUTHOR	ANIMAL	AGE(WKS)	TYPE OF FOOD	REPLACEMENT
PRESENT EXPERIMENT	CALF	3-7.5	FRESH CUT HERBAGE	0.82
DONEY <u>ET AL.</u> (1984)	LAMB	12	GRAZED PASTURE	1.06
BAKER <u>ET AL.</u> (1976)	CALF	24	GRAZED PASTURE	1.3-2.0
HODGSON(1971e)	CALF	7	CHOPPED DRIED GRASS	0.26-0.46

For example, the replacement rate for calves fed fresh pasture increased with age (see Table 4.1). The increase with age in the replacement rate may be partly due to the cumulative effect of a high level of solid food intake on reticulo-rumen development and/or an improvement in the efficiency of the eating process as the calves grow (Hodgson, 1971a). In other words, the intake of herbage or other solid feed is less severely limited for older calves than for young calves. Some mechanisms which have been suggested to control solid food intake by young ruminants (see section 1.2) give support to this observation. Generally speaking, the effects of all these control mechanisms (except for metabolic control) decline as the calves grow.

As the calves adapt to the solid food gradually, the digestive organs, particularly the reticulo-rumen as well as the salivary gland, become more suitable for solid food intake. Hodgson (1971d) suggested that the control of solid food intake by behavioural factors is more effective in younger ruminants. The high quality of the fresh cut herbage in the present experiment and grazed pasture in other experiments (Baker & Barker, 1976, Doney et al., 1984) resulted in much higher replacement rates than chopped dried grass used in Hodgson's experiment (Table 4.1).

The pattern of herbage intake development was similar for HM and LM calves and for HBI and LBI calves. It was also similar to those obtained by other workers (Baker et al. 1976, Le Du et al. 1976a, Hodgson, 1971a). The rapid increase in herbage intake which occurred after weaning was expected since the energy intake from milk was suddenly decreased to zero. Both Davies & Owen (1967) and Hodgson (1971b) have pointed towards a theory of equalization of nutrient intakes in attempting to explain negative relationships observed between liquid and solid food intakes in young ruminants. However, under the control of behavioural and/or physical control mechanisms, the calves cannot fully equalize the energy intake, especially when the quality of solid food is low. The weaning itself, as a big change of environment for young calves, may also have an influence upon the calf ingestive behaviour. Le Du et al. (1976a) observed that weaning, rather than the milk feeding level, had the main effect on calf grazing time. The weaned calves grazed for significantly longer time per day than unweaned calves but there was no difference in grazing time between calves fed different levels of milk (Le Du et al., 1976a). The slowing down of intake development with age (see Fig. 3.2), measured as organic matter intake per unit LW, was in agreement with Hodgson's work (1965, 1971a). The decline in herbage quality could only partially explain the decrease since only a small proportion of the calves in the present experiment were influenced by the dramatic decrease of herbage quality which occurred in the last two weeks of indoor feeding period (see Fig. 3.1). Alternatively, it may be suggested that the calves were approaching their peak intake per unit LW based on the physical food intake control mechanism at that

stage under the conditions of the present experiment. This suggestion is supported by the fact that the intake was lower for hay (20 g DM/Kg LW) and for pasture (20 g OM/Kg LW) than for pelleted food (30 g DM/Kg LW) in the experiment by Hodgson (1971a). These results indicated the overwhelming effect of milk feeding level on herbage intake development.

The extent of superiority of LM calves in solid food intake and the length of time this effect persists are important since they obviously determine the extent of compensatory growth of LM calves in the post-weaning period. The differences in solid food intake established in the pre-weaning period, due to the difference in milk feeding levels, persisted for two weeks in the present experiment. Thereafter they disappeared as reported by other workers (Davies & Owen, 1967, Hodgson, 1971a). It appeared that the properties of solid food offered determine the length of this period. Brookes and Davey (1977) observed that the animals restricted before weaning did not respond by increasing their DE intake of concentrate-hay diet when it was offered ad libitum after weaning. This is probably due to the greater bulky density of the concentrate food. So the physical mechanisms of solid food intake was no longer limiting the such solid food intake. So for Brookes and Davey's calves (1977), the capacity of reticulo-rumen was not a factor limiting the concentrate-hay intake for newly weaned calves whereas for calves in the present experiment the intake capacity was still an important factor in solid food intake after weaning. On the other hand, the extent of the restriction of milk intake in early age may be another factor influencing the length of the period. The disappearance of the difference in solid food intake soon after weaning suggests that the superiority of better-developed reticulo-rumen of calves fed low level of milk is always lost before the calves start eating large amounts of solid food. So the high solid food intake caused by low milk feeding level cannot be expected to be kept for a long period or have a significant effect on LW gained at a later stage. In other words, the effects of calf feeding regime upon liquid and solid food intake, and consequently on the growth performance, are largely limited to the early life of calves.



The close correlation ( $r = 0.84$ ,  $p < 0.01$ ) between herbage intake before weaning and that after weaning for the whole group of the calves (see section 3.3.2) was expected because of the effect of milk feeding level upon reticulo-rumen development (Kaiser, 1976). On the other hand, the close relationship between herbage intake before weaning and after weaning within HM treatment calves (see section 3.3.2), was in contrast with the results of some earlier experiments (Lawrence & Pearce, 1965, Davies & Owen, 1967). However, it is logical to have such a relationship since a difference in herbage intake in the pre-weaning period would also result in a difference in reticulo-rumen development. Both Hodgson (1971c) and Kirkwood & Prescott (1984) concluded that the absolute and relative size of the four stomachs of a young ruminant, or more generally the gut weight, increases with increasing food consumption. Furthermore, the factors other than milk feeding level which influenced calf solid food intake in the pre-weaning period may still have effects after weaning. But it is by no means clear what these factors and their mechanisms are.

The relatively close relationship ( $r = 0.56$ ,  $p < 0.05$ ) between the herbage consumption in the final week (9.5-10.5 wks of age) of the experiment and the growth rate of the calves thereafter until 21-25 weeks of age (see section 3.4.3) was observed. This result suggested that the herbage intake in week 10 was possibly positively correlated to the herbage intake at later stages, at least until 21-25 weeks of age. It is interesting to notice that the difference in herbage intake caused by different milk feeding levels in the pre-weaning period disappeared at the same stage, week 10 (see Table 3.5). This may suggest that there are some other factors influencing the calf herbage intake. But before weaning and shortly after weaning, the effects of these factors may be masked by milk feeding level. The relation also suggested that effects of these factors rather than that of milk feeding level have had a prolonged influence on calf voluntary herbage intake after the calves were weaned. Analysis showed that LW at the commencement of the experiment (i.e. at 3 weeks of age) was positively correlated with the herbage intake in week 10 especially for HBI calves (see section 3.3.2). For LBI calves, the correlation was not significant. This indicated that LW at that stage may be one

of the factors which influenced the herbage intake development for HBI calves. At the same time, it also indicated that the herbage intake development of HBI and LBI calves is different. Walker and Hunt's experiment (1981) with lambs showed that the birth LW, which has close correlation to later LW, was positively correlated with the pellet intake of the lambs even three weeks after weaning (weaned at 3 weeks). But the present experiment gave no clue to the possible mechanisms responsible.

There were no differences between HBI and LBI calves in herbage intake and herbage intake development pattern (Fig.3.2). The absence of differences in voluntary herbage intake between HBI and LBI calves was not quite in agreement with results of some other experiments (Davey et al., 1983, Bryant, 1983). Since the difference in breeding index of the cows is the result of selection for milk yield potential it may be difficult to relate breeding index to its possible effect on calves' growth potential or intake ability in their early age. There is no evidence yet to suggest that there is a difference in growth potential between HBI and LBI Friesian calves. Recent work at Massey has demonstrated that there are some metabolic differences between HBI and LBI calves in their early life (Mackenzie, pers. comm.). It was found that the HBI calves had high levels of insulin, glucose and growth hormone (GH) concentrations in the plasma. Roy et al.'s recent work (1983) with bull calves of three breeds (Aberdeen X Friesian, Hereford X Friesian and Friesian) demonstrated that there was a positive correlation between voluntary milk intake and insulin:GH ratio. This suggested that the calves with different insulin:GH ratios had different appetites. However, more work is needed to investigate its effect upon solid feed intake. The extreme complexity of calf voluntary solid feed intake control mechanisms makes it difficult to relate the voluntary milk intake and solid feed intake directly.

HBI calves in the HM treatment suffered a sudden decrease in herbage intake during the last week of the indoor feeding period (aged 10.5 weeks) (Fig. 3.2). This group of calves also had the lowest LW at 21-25 weeks of age (see Table 3.7). So, this group of calves presumably also had a low intake level in the post-experimental period.

While this fact probably ruled out the possibility of intake measurement mistakes, it was not quite clear what caused the sudden depression in herbage intake. A decline in herbage quality could have been the cause since two of the four calves in this group were finished later and might have been influenced by the decrease in herbage quality. This result and the positive relation between herbage intake in week 10 and calf growth rate in the period from 10 to 21-25 weeks of age for the whole group of the calves in the present study demonstrated the importance of avoiding the severe depression of calf herbage intake in their early age, even after weaning.

The significant differences between the ash contents and the in vitro digestibilities of herbage offered and refused (see Table 3.6), indicated that the calves selected the herbage offered to them during ingestion process in the stall feeding situation, as observed in grazing. They selected the herbage with higher in vitro DOMD values. The difference in ash contents also suggested that the calves avoided the herbage contaminated by soil in the process of ingestion. This is in agreement with Keane & Harte's (1982, 1983) report. This fact may also indicate that the criterion for selection used by calves during ingestion is probably based on nutritive value of the feed. Furthermore, it may be postulated that calves' herbage intake in the present experiment, or other indoor feeding experiments fed fresh cut herbage (e.g. Keane & Harte, 1982), is also likely to be limited by the amount of herbage offered since the herbage allowance for ad libitum intake is generally lower than that in most of the grazing experiments with calves (Baker & Barker, 1977, Roy, 1980).

Since only one type of fresh cut herbage was used in the present experiment, it is difficult to detect the effect of herbage quality on calf voluntary herbage consumption. Though the herbage quality declined gradually as the pasture grew, however, this effect was probably confounded by the growth of calves (LW increase and behavioural change) and the weaning effect. The increase of the herbage consumption per unit LW (see Fig. 3.2) showed the general trend of intake development. The curvilinear relation between age and intake in the pre-weaning period was probably due to the effect of a constant milk intake level. The constant milk feeding level over the

whole pre-weaning period rather than changing the amount of milk offered with LW change caused the gradual increase in the gap between potential energy requirement (i.e. the maintenance requirement + potential growth requirement) and energy offered in milk. It is quite logical that the calves would try harder to ingest more solid food to satisfy their energy requirements as suggested by Hodgson (1975).

There was a negative correlation ( $r = -0.70$ ) between herbage intake and herbage digestibility measured on individual calves in the post-weaning period. Since the quality of the herbage offered to the calves at one time can be considered to be uniform, the differences in digestibility may only be attributed to the calf's ability to digest solid feed. Some earlier evidence suggested that the variation in digestibility of feed was caused by the feed intake level (see section 4.3.1 for detailed discussion).

#### 4.2 CALF GROWTH PERFORMANCE

The differences in calf growth rate between HM and LM calves were in accordance with their total metabolizable energy intakes (Fig.3.7). The HM calves' growth rate was within the range of LW gain generally recommended for heifer rearing (Davey, 1974, Scott and Smeaton, 1980). The LM calves grew more slowly but this may not be considered to be important in practice for heifer calf rearing, because 1) grazing calves may have improved growth performance, 2) many workers have shown that for heifers, a slow growth rate at 3 or 4 weeks of age has little influence on later growth rate. So under conditions of high levels of pasture feeding, the difference in LW may not persist long (Davey, 1962). The difference in growth rate in the pre-weaning period between HM and LM calves has not resulted in a significant difference in LW at weaning in the present experiment (see Table 3.7). This was to be expected because of the short period during which the calves received different level of milk feeding and the relatively large variation (C.V.% = 8%) in LW at the beginning of the experiment and the big variation in growth rate (C.V.% = 17%). The pre-weaning growth performance of the calves in the present experiment was similar to that in other experiments where calves were fed similar levels of

milk (e.g. Hodgson, 1971a, Kaiser, 1976).

For the whole group of calves, the growth response, to one Kg of additional milk intake, was 73 g in the present experiment. This is in the range of 55 to 81 g given by Baker & Barker (1977) and Baker et al. (1976). In the present experiment, the quality of the liquid feed (whole milk) must have been higher than that in their experiments (reconstituted milk) and the herbage intake lower, than in the grazing situation. So the disadvantage of low herbage intake might be offset by extra milk energy intake. Considered from an energy intake point of view, the calves growth rates were closely correlated to their metabolizable energy intakes (MEI). But there appears to be a difference in the regression coefficients between HM and LM groups (see section 3.4.1.2 and Fig.3.7). The HM calves responded more favourable to the increase of MEI. The high quality of the milk energy is the most likely reason for this. The Kg efficiency of ME used for gain) of milk or milk substitutes is about 0.7, ranging from 0.67 to 0.81, whereas for herbage it may be as low as 0.4-0.5 (ARC, 1980).

The absence of a difference in growth rate between HM and LM calves in the three weeks following weaning was due to the big variation of growth rate in this period (C.V.% = 31%). This was in accordance with the big variation in herbage intake in this period. It is not clear why the intake was so variable but a reason may be the relatively small differences in milk intakes in the pre-weaning period. The LW may also have an effect on the intake of herbage but the effect was not significant for the first two weeks following weaning.

The calf growth rate in the post-experimental period was not affected by milk feeding level in the present experiment. This was in accordance with Davey's earlier work (1962). It was also in accordance with the fact that the differences in herbage intake caused by different milk feeding level disappeared just two weeks following weaning. The growth rate of calves in this period had significant effect on the calf LW gain in the whole period (from 3 to 21-25 weeks of age). This was shown by the big positive correlation coefficient ( $r = 0.90$ ) between overall growth rate and growth rate in period III

(from 10.5 to 21-25 weeks of age). In contrast to this, the growth rate in the pre-weaning period had no effect on calves growth rates over the whole period (see section 3.4). This was in agreement with the suggestion that the lower growth rate after 3 weeks of age has no detrimental effect on later growth performance as already proposed by Davey in 1974. The results of the experiment suggest that under low to moderate milk feeding level with the calves weaned before 8 weeks of age, the milk feeding level after 3 or 4 weeks of age has no important effect on calf LW and post-weaning management and growth rate is more important in determining calf LW at a later stage.

It was found that calf LW at the commencement of the experiment (3 weeks of age) was correlated ( $r = 0.55$ ) with the calves' overall growth rate (see section 3.4). This result was similar to that reported by Baker & Barker (1977) though the initial age of their calves was 7 weeks old. The analysis of the relations between some relevant factors demonstrated that firstly, there was a close relationship ( $r = 0.87$ ,  $p < 0.01$ ) between calf LW at three weeks of age and digestibility of herbage after weaning (see section 3.5.2). This is indirectly supported by Jeffery's work with sheep (1976). He showed that for every Kg LW increase the digestibility of diet increased 0.34% while in the present work, it was 0.63%. Secondly, the relationship between LW and calf intake in the final week of the indoor feeding period was also significant ( $r = 0.62$ ,  $p < 0.05$ ). These relations might point towards two aspects of the effect of LW at an early age upon calf growth performance at later stage (up to about six months old in the present experiment). However, the mechanism of such a function of the calf LW in early age upon the digestibility or intake is not clear. The effect of LW upon intake can be considered as a result of a bigger energy requirement and the bigger solid feed intake, in turn, promotes the development of the reticulo-rumen (Hodgson, 1971c). The large amount of herbage ingested pre-weaning also promoted the development of digestive ability, therefore, the digestibility in the post-weaning period was not only correlated with the LW at the commencement of the experiment but also with the herbage intake in the pre-weaning period (see section 3.5.2). These results support the theory that calves should be well fed in the first few

weeks of life in order to ensure the better growth at later stages. But caution must be paid to the fact that the LW difference at the commencement of the present experiment as well as in Baker & Barker's experiment (1977) was a mixed effect of birth LW and random variation of growth rate before the commencement of the experiment since these calves were fed similarly before the experiment. So any difference in their growth rate could be due their intake ability difference or utilization efficiency. Evidence on the effect of birth LW on development of solid feed intake, in literature, is rather confused at the present stage (see section 1.2.2.1).

### 4.3 DIGESTION AND NITROGEN METABOLISM

#### 4.3.1 Digestion

The digestion of calf rations always attracts a lot of attention from research workers because of the significance of the early utilization of solid feed. The positive relation between digestibility of the whole diet and milk feeding level, or milk:herbage organic matter intake ratio, supports the conclusion that young ruminants can digest milk or other liquid feeds better than solid feeds (Roy, 1980). Theoretically, on the assumption that the milk digestion and solid feed digestion do not interfere with each other, as observed by Penning & Gibb (1978) in lambs, the digestibility of the whole diet (mixture of liquid feed and solid feed) should be linearly related to the proportion of milk organic matter in the diet. That is, as the milk proportion in the diet increases, the digestibility of the diet increases until it reaches the digestibility of milk. Both the theoretical relation and the actual relation obtained by plotting the digestibility of the diet against the proportion of milk in the diet is shown in Fig 4.2. The theoretical relation was on the basis of 94.3% milk OM digestibility (see section 3.5.1) and 75% herbage OM digestibility, which was obtained by deduction method on 94.3% milk OM digestibility. The comparison of the two relations suggested that the digestibility of diet of calves fed low level of milk was slightly improved (see Fig.

4.2). This was also indicated by comparing herbage digestibility obtained by extrapolation to zero milk intake (which was 78.9%) with the average digestibility of herbage obtained by deduction method (75.00%). That is to say, at a low level of milk feeding, the actual digestibility of the whole diet was better than predicted from the above assumption. Such an improvement in digestibility of the diet is probably related to the total feeding level. Calves offered lower level of milk usually have lower total DM or OM intake. Some earlier experiments have shown that the digestibility of individual animals is negatively correlated with their feeding level (Raymond & Minson, 1959, Anderson *et al.*, 1959, Leaver *et al.*, 1969). In the present experiment, because of the effect of milk, the correlation between digestibility of the diet and the organic matter intake was not significant ( $p > 0.05$ ). Such an improvement of diet digestibility was likely a result of the modification of digestion process. But it was not clear digestibility of which part of the diet, milk or herbage or both of them, was improved.

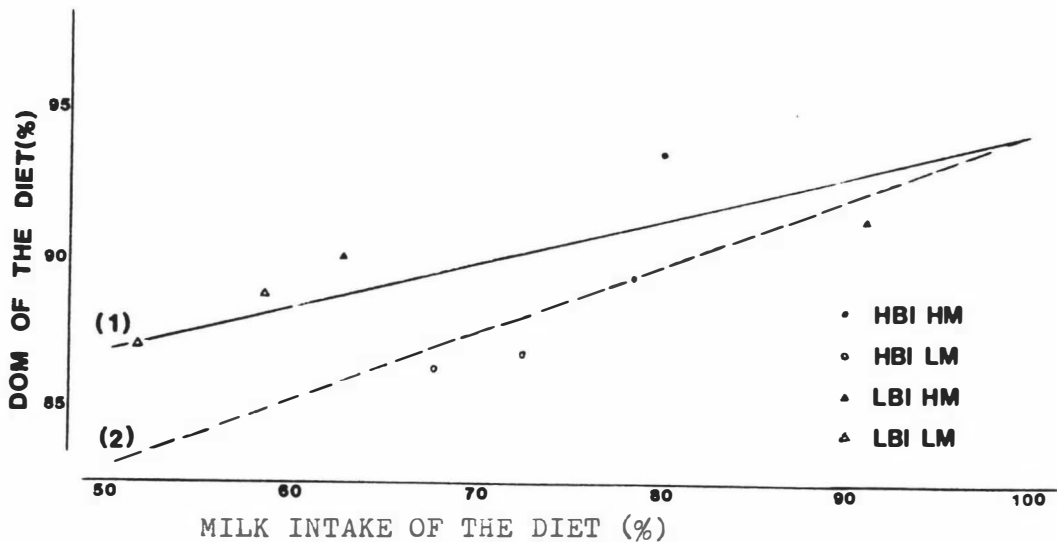


FIG. 4.2 The Comparison of Relationships between Milk Intake and Digestibility of the Diet

The digestibility of herbage appeared not to have been improved significantly after weaning. Also, there was no correlation between herbage digestibility in the pre-weaning and post-weaning period. This



is in agreement with the general belief that the calf's ability to digest high quality solid feed develops at an early age (Hodgson, 1971c). But the comparison of variation in herbage digestibility of the whole group of calves showed that it was more variable in the pre-weaning period (C.V.% = 10.7%) than in the post-weaning period (C.V.% = 3.7%). This result was similar to that reported by Preston et al. (1957) and Byford (1974). This change of variation probably suggested that the development of digestion in the pre-weaning period was not uniform and more variable than post-weaning stage. But the poor digestion of some individuals was improved after weaning, therefore the difference between calves decreased. Over the period of the pre- to post-weaning digestibility trials (at approximately the 4th to 9th weeks of the experiment), the decline in pasture quality was small (see Fig. 3.1), so the absence of digestibility improvement could not be attributed to the change in feed quality.

Before weaning, the interaction of milk feeding and total feeding level made the relationship between the intake level and digestibility of individual calves unclear (see above discussion). So it is not surprising that once the calves were weaned, the relationship between herbage intake and herbage digestibility became significantly established. This confirmed some earlier workers' results (Raymond & Minson, 1959, Anderson et al., 1959, Leaver et al., 1969). They showed with adult ruminants that the digestibility of diet was negatively correlated with the feeding level of the animal. Hodgson's experiment (1971e) with calves gave similar results. He observed that a high feed consumption was associated with a fast passage rate of digesta and consequently low digestibility of the diet. Leibholz (1976) also showed that a greater food intake resulted in a greater flow of OM digesta to the duodenum. For young ruminants, the gut capacity, especially the reticulo-rumen size, may determine the extent to which feeding level has an effect upon digestibility in a particular animal. The greater capacity results in more solid feed being held in the gut rather than being passed down quickly.

There was no sound evidence from the present experiment to suggest that there is a difference in solid feed digestibility between HBI and LBI calves.

#### 4.3.2 Nitrogen Metabolism

The absence of significant differences in most of the nitrogen metabolism parameters tested (see Tables 3.23, 3.24) indicated the similarity of nitrogen metabolism between milk treatments and BI groups. However, the difference in milk nitrogen intake did result in a difference in the apparent digestibility of nitrogen. The HM calves had a higher apparent nitrogen digestibility than LM calves had. This was expected since the digestibility of milk protein is higher than that of herbage protein.

The relationship between nitrogen retention (NR) and nitrogen intake (NI) per metabolic weight (LW) is shown in section 3.5. From the extrapolation to zero nitrogen retention, nitrogen requirement for maintenance (Nm) was  $0.428 \text{ gN/Kg}^{0.75}/\text{d}$  for the whole group of calves. This value was somewhat higher than those reported by Hughes in 1977 ( $0.35 \text{ gN/Kg}^{0.75}/\text{d}$ ) and Stobo & Roy in 1973 ( $0.33 \text{ gN/Kg}^{0.75}/\text{d}$ ). It may be due to the lower quality of herbage protein. The diet in the present experiment consisted of milk and herbage in period I and herbage only in period II whereas in Hughes' experiment it was milk plus meal. The digestibility of herbage protein in the present experiment was 74.5% compared with 80.9% in Hughes' experiment (1977).

#### 4.4 CALF HEALTH

Though five calves scoured in the pre-weaning period, there was no evidence to suggest that scouring had a severe effect on calf performance in the present experiment ( $p > 0.05$ ). Therefore, all the data were included in the analysis.

The "bloated" phenomenon observed on calf No 33 seemed to be the result of incomplete closure of the oesophageal groove since the change of feeding procedures from bucket feeding to teat sucking improved the situation promptly. Nevertheless, the calf's herbage consumption, digestibility and growth performance were somewhat lower than those of other calves in the same treatment. Unfortunately, no conclusion can be reached because of lack of data on pH and composition of rumen content. But the case was quite like that

reported by Lawlor & Kealy (1971) as "maladjustment syndrome" in artificially reared lambs. Their work showed that it was related to the incomplete closure of the oesophageal groove and it occurred only to a few individuals. The data from this calf were also included in the analysis of the result since it was not extremely abnormal and also for the convenience of the statistical analysis.

#### 4.5 CONCLUSION

The results showed that low levels of milk intake, which cannot meet the requirements of growth potential of the calves for nutrients, will result in increased herbage intake to fill the deficit but this does not compensate fully for the decreased milk energy intake. Consequently, calf growth performance is always decreased by low levels of milk intake. There appeared to be no differences in responses in herbage intake to different milk feeding levels for HBI and LBI calves. The overall DE intake over the two periods is similar for HM and LM calves. The results suggested that the difference in herbage intake in the third week after weaning had a prolonged effect on calf herbage intake. LW at the commencement of the experiment, 3 weeks of age, was shown to have a significant effect on calf herbage intake in the final week of the experiment, week 10, and herbage digestibility at the same stage. This may explain the significant effect of initial LW on the calf growth rate after weaning at 10 weeks of age until 21-25 weeks of age. This supports the long recognized theory that calves should be well fed in the first few weeks of life since poor growth performance in that period has a detrimental effect on later growth performance. On the other hand, after 3 weeks of age, relatively low levels of milk feeding are likely to have an encouraging effect on calf solid feed intake development and have no detrimental effect on calf growth performance in the long term. Post-weaning management largely determines the overall growth rate after 3 weeks of age until about 6 months of age.

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APPENDIX ONE

Table 1 Analysis of Variance of Calf Growth Rate  
over the Whole Experimental Period

SOURCE OF VARIATION	DF	SS	MS	F value	
BI	1	25	25	0.284	NS
ML	1	3	3	0.034	NS
INTERACTION	1	26	26	0.289	NS
ERROR	12	1071	89		
TOTAL	15	1125			

Table 2 Analysis of Variance of Calf Growth Rate in Period I

SOURCE OF VARIATION	DF	SS	MS	F value	
BI	1	15.60	15.60	2.10	NS
ML	1	72.37	72.37	10.18	**
INTERACTION	1	11.17	11.17	1.57	NS
ERROR	11	78.20	7.11		
TOTAL	14	167.57			

Table 3 Analysis of Variance on Calf Weaning Weight


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SOURCE OF VARIATION	DF	SS	MS	F value	
BI	1	61.04	61.04	1.228	NS
ML	1	5.35	5.35	0.108	NS
INTERACTION	1	0.19	0.19	0.004	NS
ERROR	12	596.52	49.71		
TOTAL	15	663.09			

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Table 4 Analysis of Variance on Calf Growth Rate in Period II


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SOURCE OF VARIATION	DF	SS	MS	F value	
BI	1	19.60	19.60	1.139	NS
ML	1	34.23	34.23	1.988	NS
INTERACTION	1	0.03	0.03	0.001	NS
ERROR	12	206.50	17.21		
TOTAL	15	260.40			

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Table 5 Analysis of Variance on Calf Growth Rate in Period III


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SOURCE OF VARIATION	DF	SS	MS	F value	
BI	1	2.25	2.25	0.013	NS
ML	1	56.25	56.25	0.331	NS
INTERACTION	1	36.00	36.00	0.205	NS
ERROR	12	2102.50	175.20		
TOTAL	15	2197.00			

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Table 6 Analysis of Variance on DOM of the Diet in Period I


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SOURCE OF VARIATION	DF	SS	MS	F value	
BI	1	0.17	0.17	0.062	NS
ML	1	30.15	30.15	10.862	*
INTERACTION	1	1.99	1.99	0.717	NS
ERROR	4	11.10	2.78		
TOTAL	7	43.41			

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Table 7 Analysis of Variance on DOM of Herbage in Period II


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SOURCE OF VARIATION	DF	SS	MS	F value	
BI	1	5.04	5.04	0.657	NS
ML	1	19.56	19.56	2.548	NS
INTERACTION	1	2.32	2.32	0.302	NS
ERROR	4	30.71	7.68		
TOTAL	7	57.63			

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APPENDIX TWOTHE DIET AND HERBAGE OM DIGESTIBILITY OF THE CALVES

Calf No.	Treatment	BI	Period I		Period II
			Whole Diet	Herbage*	Herbage
13	HM	HBI	93.36	84.60	77.37
42	HM	HBI	89.27	70.90	79.05
10	HM	LBI	91.31	64.00	84.00
32	HM	LBI	90.09	83.00	77.75
6	LM	HBI	86.27	69.50	74.20
33	LM	HBI	86.60	66.60	78.12
8	LM	LBI	88.76	81.00	77.69
36	LM	LBI	86.69	70.90	79.05
MEAN			98.05	74.85	77.98
C.V.(%)			2.83	10.65	3.68

\* obtained by deduction method on the assumption of milk digestibility is 94.3%.